Prepared for:
Arizona Public Service – Four Corners Power Plant
Fruitland, New Mexico

BART Visibility Modeling Report for the Arizona Public Service Four Corners Power Plant

ENSR Corporation
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Executive Summary

The Arizona Public Service Company (APS) operates the Four Corners Power Plant ("FCPP"), a privately owned and operated coal-fired power plant located in Navajo Indian Reservation, about 25 miles west of Farmington, New Mexico. The Best Available Retrofit Technology (BART) analysis for Four Corners is under the jurisdiction of EPA Region 9.

During 2004 and 2005, FCPP undertook a testing program to increase the plant's SO_2 control level from 72% to 85%. This test program was undertaken with the concurrence of the US EPA Region IX, the National Park Service (NPS), the Navajo Nation EPA, and several environmental interest groups. The testing demonstrated that the plant could actually increase its SO_2 control to 88% on an annual average basis. Based on that finding, FCPP voluntarily agreed to accept that level of SO_2 controls as an enforceable emission control level for the Plant. This new control level reduced the Plant's annual emissions of SO_2 by about 25,000 tons per year. A Federal Implementation Plan (FIP) for the FCPP (published in the May 7, 2007 issue of the Federal Register), concluded that 88% SO_2 control level on an annual basis was equivalent to BART level for the FCPP.

The large Units 4 and 5 at FCPP have state-of-the-art particulate baghouse controls, while the smaller Units 1-3 have venturi scrubber controls for PM_{10}.

One PM_{10} BART control case for Units 1-3 and three BART NO_x control cases were modeled using CALPUFF for each of three meteorological years (2001-2003) and several nearby Class I areas. The BART control options were as follows:

PM_{10} Control Option 1: fabric filter (baghouse) controls on Units 1-3.

<u>NO_x Control Option 1</u>: Advanced combustion controls (low NO_x burners (LNB) on all units and overfire furnace air (OFA) on Units 3-5).

<u>NO_x Control Option 2</u>: Advanced combustion controls (LNB/OFA) on Units 1-5 in combination with High Energy Reagent Technology (HERT) on Units 1-3 and in combination with selective non-catalytic reduction (SNCR) on Units 4-5.

<u>NO_x Control Option 3</u>: Advanced combustion controls (LNB/OFA) in combination with selective catalytic reduction (SCR) on Units 1-5.

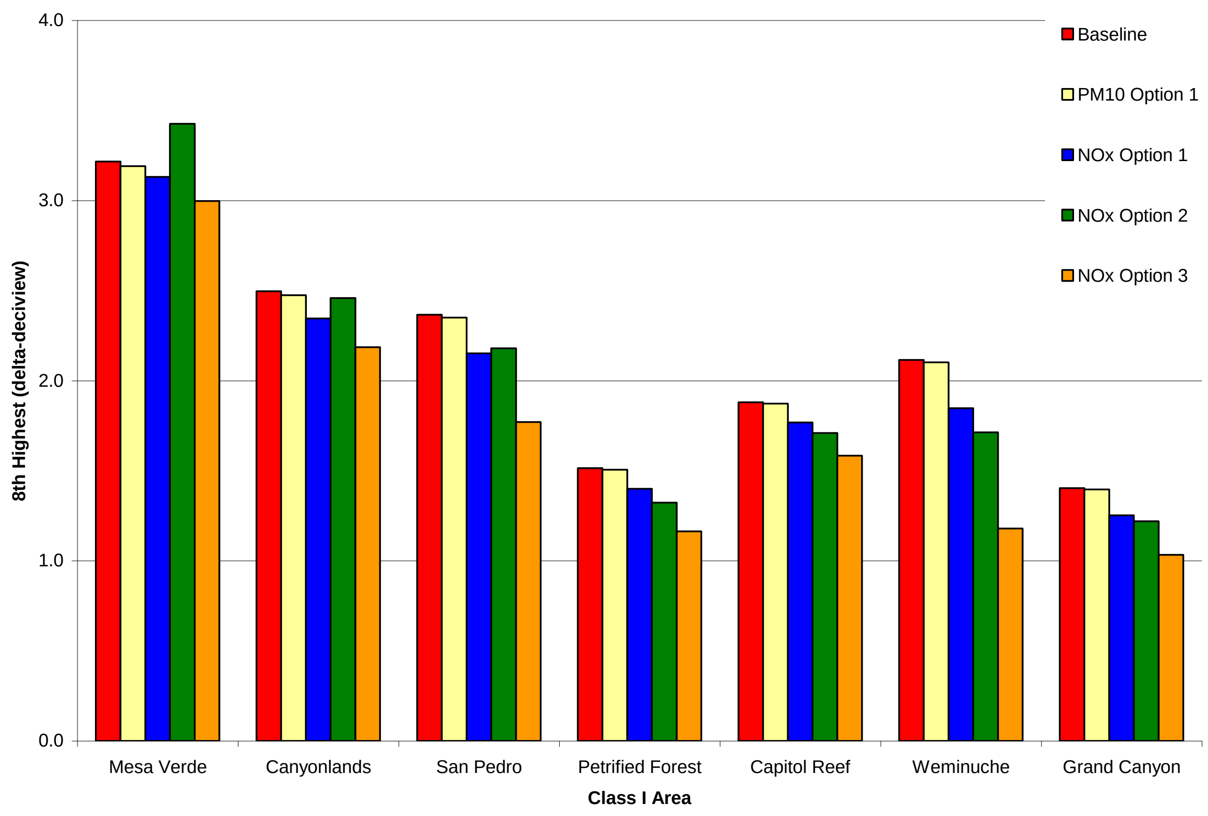
Modeling results were obtained for each of the 16 PSD Class I areas within 300 km of the FCPP. The highest impacts occur at the closest Class I areas in various directions, so modeling results are also reported for the closest 7 Class I areas. For only PM_{10} controls, the results show that the regional haze impacts averaged over the closest 7 Class I areas may improve visibility by an average of only 0.01 delta-dv (relative to the baseline case), so this control option is not cost effective.

NO_x presumptive BART limits apply to FCPP Units 3-4-5 (0.39 lb/MMBtu for Unit 3 and 0.40 lb/MMBtu for Units 4-5) since the plant capacity exceeds 750 MW, and these units all exceed 200 MW. NO_x presumptive BART limits do not apply to Units 1-2 since they do not exceed 200 MW.

NO_x control option 1 will result in NO_x emission rates below the presumptive limit for Units 3-4-5. For NO_x Control Option 1, the visibility improvement averaged over the 7 closest Class I areas is 0.16 delta-dv (relative to the baseline case). Addition of SNCR (NO_x control option 2) shows visibility degradation at Mesa Verde National Park (the closest Class I area) due to additional ammonia emissions, and only a slight (0.14 delta-dv) regional haze improvement when averaged over the closest seven Class I areas – a smaller average visibility improvement than that projected for NOx Control Option 1. This poor performance under Option 2 reflects the fact that SNCR operations can increase the ambient ammonia concentration by about 0.2 ppb and result in additional sulfate and nitrate particulate formation. Therefore, this NO_x control option is not effective in improving visibility.

Addition of SCR (NO_x control option 3) may improve visibility by about 0.44 delta-dv (averaged over the seven closest Class I Areas) from the baseline case. The incremental improvement of option 3 over option 1 is only about 0.28 delta-dv. This change is small compared to the deciview change that is perceptible by humans (about 1-2 delta deciviews) and is less than the "contribution" threshold of 0.5 delta-dv. The relatively small incremental improvement in visibility is due in part to the small role that nitrates play in the total regional haze contribution, especially in summer. In addition, the installation of SCR would create new emissions of primary sulfates (H_2SO_4) and excess ammonia, partially offsetting any available NO_x reduction benefit to visibility. This is especially true during the high visitation period of the warm weather months, when nitrates have a minimal contribution to visibility impairment, but sulfates have an important role. Therefore, NO_x emission controls involving SCR are relatively ineffective in this case, especially taking into account the high cost of the controls. Figure ES-1 shows the changes in visibility impact among the NO_x control cases for each of the closest 7 PSD Class I areas.

Figure ES-1 8th Highest Regional Haze Impacts Averaged Over 3-Years Due to Baseline and BART Control Emissions



1.0 Introduction

1.1 Source Description

The Arizona Public Service Company (APS) operates the Four Corners Power Plant ("Four Corners" or "FCPP"), a privately owned and operated coal-fired power plant located on the Navajo Nation, about 25 miles west of Farmington, New Mexico. The facility consists of five generating units, with a total capacity of approximately 2,060 megawatts.

The BART analysis for Four Corners is under the jurisdiction of EPA Region 9, and the analysis will be reviewed and approved by EPA Region 9.

1.2 History of Emission Reductions at FCPP

FCPP Units 1-5 were constructed between 1962 and 1970. An SO_2 removal efficiency of 50% was obtained for Units 1-2-3 in the early 80s by retrofitting the venturi particulate scrubbers with lime injection. Lime spray towers were added to Units 4-5 and SO_2 removal was increased to 72% Plant-wide in the mid 80s.

In the late 1990s, APS initiated a dialog with four environmental interest groups involved in environmental issues in the western United States: Environmental Defense, the Grand Canyon Trust, Western Resource Advocates and the New Mexico Citizens for Clean Air and Water. The dialog focused on the issue of visibility in the western United States. The dialog focused on improved SO_2 control primarily because that pollutant had much higher visibility impact than NO_x emissions. In 2003, APS and these environmental groups agreed on a proposal geared to further reduce sulfur dioxide emissions at the Four Corners plant utilizing an 18-month test program. The test program involved certain phased operational changes and scrubber chemical process changes to increase annual sulfur dioxide control levels from 72% to 85% without triggering operational problems. APS and the environmental groups jointly presented that proposal to the EPA, the Navajo EPA and the National Park Service. With the support of these groups, APS initiated the test program in early 2004. The test program was completed during the summer of 2005. APS prepared a report concluding that the plant was not only able to meet the goal set in the proposal, but could also improve the annual average sulfur dioxide controls to an 88% removal efficiency. At that elevated control level, the plant was able to cut its annual sulfur dioxide emissions by more than 55 percent, compared to the pre-test level.

After the testing program, the Navajo Nation and the stakeholders group requested that EPA include these negotiated, additional SO_2 emissions reductions into a source-specific Federal Implementation Plan (FIP) for the FCCP. FCPP agreed to increase the amount of SO_2 emissions it was eliminating from its exhaust stream from 72% to 88%, thereby reducing its annual emissions of SO_2 to the atmosphere by about 25,000 tons per year. APS and the environmental groups then worked with the reviewing agencies to incorporate the higher sulfur dioxide control level as an enforceable emission limit for the plant through the FIP.

The FIP, published in the May 7, 2007 issue of the Federal Register, provides EPA's policy on whether the agreed-upon SO_2 controls are BART equivalent, with excerpts provided here:

"As noted in the preamble to the proposed FIP, the level of control in the FIP for FCPP is "close to or the equivalent" of BART for this source. EPA agrees that if the Agency were to undertake a case-by-case BART analysis, BART could potentially be determined to be a greater level of control than 88% SO_2 removal. However, any case-by-case BART analysis would be subject to the timeframes needed to implement such controls. EPA has the discretion to promulgate FIPs, as necessary or appropriate, within reasonable timeframes to protect air quality in Indian country. In today's rulemaking EPA is exercising its discretion under 40 CFR 49.11 to find that it is neither necessary or appropriate at this time to undertake a BART determination for SO_2 for FCPP given the timing of the substantial SO_2 reductions resulting from this FIP.

Moreover, as explained in the preamble to the 2006 proposed FIP, there are only two major sources of SO_2 on the Navajo Reservation that are potentially subject to the BART requirements--Navajo Generating Station and FCPP. 71 FR at 53632. EPA determined previously that the SO_2 emission limits in the 1991 FIP for the Navajo Generating Station provide for greater reasonable progress toward the national visibility goal than would BART. 71 FR at 53633. As explained above, given that the SO_2 controls for FCPP immediately achieve significant reductions in SO_2 comparable to what could ultimately be achieved through a formal BART determination, EPA believes that it will not be necessary or appropriate to develop a regional haze plan to address SO_2 for the Navajo Nation in the near term."

The dialog with these environmental groups also dealt with NO_x emissions. APS, in consultation with the environmental groups, hired an independent consultant charged with assessing the potential for reducing the plant's NO_x emissions, through additional combustion controls. The consultant's report concluded there was little room for improving combustion controls at the three smaller units, although further detailed evaluations were needed to assess potential combustion controls for the two larger units. APS has continued to study such control options as part of the Best Available Retrofit Technology program.

The large Units 4 and 5 at FCPP have state-of-the-art particulate baghouse controls, while the smaller Units 1-3 have venturi scrubber controls. One of the BART control options tested considers the expected visibility improvement if baghouse controls were to also be installed on Units 1-3.

1.3 BART Requirements

Federal regulations under 40 CFR Part 51, Appendix Y provide guidance for conducting a visibility impairment analysis for designated eligible sources. The program requires the evaluation of the Best Available Retrofit Technology (BART) for existing eligible sources and corresponding visibility impacts, in order to help meet the targets for visibility improvement at designated Class I areas.

Four Corners has been identified as a source that is eligible for consideration of BART controls for NO_x and particulate, as discussed in Section 1.2. ENSR conducted BART exemption modeling of Units 1-5, and the results indicated that these units are subject to BART review because the predicted visibility impacts with baseline emissions exceed 0.5 delta deciviews in at least one Class I area.

This BART analysis report discusses CALPUFF modeling results of the baseline case and the BART control options that were modeled.

1.4 Overview of BART Modeling Analysis

The site-specific BART visibility improvement analysis provided in this report includes the following components:

- A list of candidate retrofit controls that are being considered;
- A discussion of the control effectiveness and resulting emission rates for each feasible retrofit technology that is considered as BART;
- An evaluation of the impacts of each site-specific BART option, including
  - An estimate of the annualized cost for each of the BART options;
  - An evaluation of the impacts on visibility for each of the BART options; and
  - The visibility improvement for each control option in terms of dollar per deciview improvement.

1.5 Report Outline

Section 2 of this protocol describes meteorological and monitoring data. Section 3 discusses CALPUFF modeling parameters and technical options used in the modeling. Section 4 describes the formation of sulfates and nitrates and their effect on emission controls. BART eligibility analysis and the baseline emissions modeling results are discussed in Section 5. Section 6 describes BART control options and the modeling results. References are provided in Section 7.

2.0 Meteorological and Monitoring Data

For the refined CALPUFF modeling, FCPP followed the Western Regional Air Partnership (WRAP) common BART modeling protocol with the exception of the model version and a few refinements to CALMET settings. These differences are discussed below in Section 2.2.

2.1 WRAP CALMET Database

The WRAP has developed six 4-km CALMET meteorological databases for three years (2001-2003). The CALMET modeling domains are strategically designed to cover all potential BART eligible sources within WRAP states and all PSD Class I areas within 300 km of those sources. The extents of the six domains are shown in Figure 3-1a through Figure 3-1f of the WRAP common BART modeling protocol, available at http://pah.cert.ucr.edu/aqm/308/bart/WRAP_RMC_BART_Protocol_Aug15_2006.pdf. The BART modeling for Four Corners was done using the New Mexico domain, as shown in Figure 2-1 of this report. The WRAP CALMET meteorological inputs, technical options, and processing steps are described in Sections 2 and 3 of the WRAP protocol.

USGS 3 arc-second Digital Elevation Model (DEM) files were used by WRAP to generate the terrain data at 4-km resolution for input to the six CALMET runs. Likewise, the Composite Theme Grid format (CTG) files using Level I USGS land use categories were used by WRAP to generate the land use data at 4-km resolution for input to the six CALMET runs. See Sections 3.1.1.3 and 3.1.1.4 of the WRAP common BART modeling protocol for more details on the data processing.

Three years of 36-km MM5 data (2001-2003) were used by WRAP to generate the 4-km sub-regional meteorological datasets. Section 2 of the WRAP protocol discusses MM5 data extraction. The BART CALPUFF modeling for FCPP was done using the New Mexico 4-km CALMET database with application-specific modifications described in the next section of the report. CALMET meteorological inputs, technical options, and processing steps were identical to those specified in the WRAP common BART modeling protocol with the exception of only R1, R2, and RMAX1, and the model version. These differences are listed in Table 2-1 and are further discussed below.

Figure 2-1 WRAP CALMET Modeling Domain for New Mexico

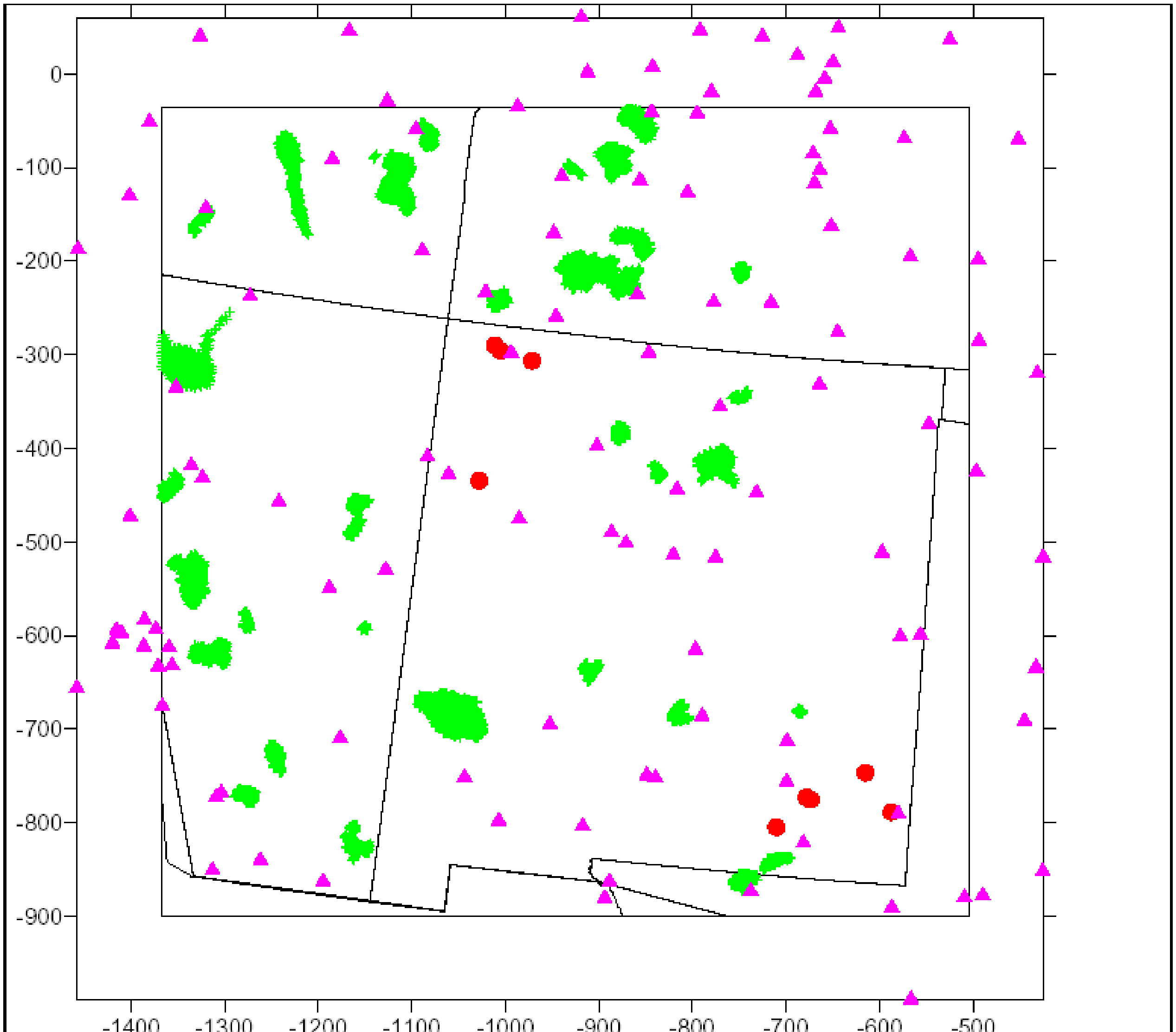


Figure 3-1c. Proposed CALMET/CALPUFF modeling domain, Class I area receptors (green), observed surface meteorological sites (purple triangles) and potential BART-eligible source locations (red circles) for New Mexico.

2.2 Enhancements to the CALMET Processing

ENSR made two refinements to the 4-km New Mexico CALMET WRAP database. They are as follows:

1. Weighting Factors for Modifying the Step 1 Wind Field. The 4-km New Mexico CALMET database has been produced by ENSR using the downloaded CALMET inputs from the WRAP website http://pah.cert.ucr.edu/aqm/308/bart/calpuff/calmet_inputs/nm/. ENSR initially ran CALMET with the setting suggested in the WRAP BART modeling protocol. As part of ENSR's internal quality assurance procedure, we displayed and examined the 4-km New Mexico WRAP CALMET wind fields in the visualization software CALDESK. Figure 2-2 graphically shows wind fields with the WRAP settings for a typical hour. Arrows represent wind direction and wind speed for that hour at a 10-meter height. Circular areas in these figures with common winds and abrupt transitions at the edge of the circles indicate a radius of influence of surface stations, R1, which was set to 100 km, as suggested in the WRAP BART protocol. The R1 value was coupled with R1MAX = 50 km, so that the influence of the surface stations is established out to 50 km and then it abruptly ends beyond that distance. Setting R1 and R1MAX to such high values is not recommended by the model developer and Federal Land Managers, especially with MM5 data resolution of 36 km with areas of complex terrain. Typically, R1 is set to a fairly small value, generally not exceeding half of the MM5 data resolution (18 km), according to recent guidance on multiple PSD projects involving CALPUFF modeling in the WRAP region from John Notar of the National Park Service (personal correspondence between John Notar of the NPS and Bob Paine of ENSR). A large R1 value results in wind fields surrounding surface stations that overwrite the MM5 wind fields, which do have terrain influences incorporated into them. In many instances, the extended extrapolation of the surface station data with an abrupt transition at 50 km produces opposing wind directions in adjacent grid squares at the 50 km distance.

To avoid this problematic wind field result, ENSR used a smaller R1 value of 18 km and R1MAX value of 30 km. The resulting wind fields for the same hour and height are depicted in Figure 2-3. The adjusted R1 and R1MAX values blend the surface observations into the MM5 observations much better, creating a more uniform wind field throughout the domain. Therefore, ENSR used the smaller R1 and R1MAX values to be more consistent with FLM guidance and due to the better performance in the wind field depiction associated with the smaller values.

2. Official EPA CALPUFF Version. When rerunning CALMET, ENSR used the latest EPA-approved version of the CALPUFF modeling system CALMET (Version 5.8, Level 070623) instead of Version 6.211 that was used by WRAP, available at http://www.src.com/calpuff/download/download.htm#EPA_VERSION. CALPUFF version 6 is basically equivalent to the VISTAS version of CALPUFF, Version 5.756. At the time of the WRAP BART protocol development process, the VISTAS version and Version 6 were generally acknowledged to be the latest and best versions available. However, EPA's deliberate attempt to review the nature of the changes between the previous official version (5.711a) and the VISTAS version (and Version 6) uncovered a number of issues that were of concern to EPA. These issues were discussed in a presentation by Mr. Dennis Atkinson of EPA's Office of Air Quality Planning and Standards at the 2007 annual modelers workshop (see http://www.cleanairinfo.com/regionalstatelocalmodelingworkshop/agenda.htm; "CALPUFF_status_update.pdf"). The basic issues of concern with the VISTAS version (and equivalent Version 6) are as follows:

- There were unexplained and unresolved large differences between Versions 5.711a and 5.756.
- Incomplete model documentation has been a problem with the last model users guides now 7 years old.
- The VISTAS code changes went beyond just fixing coding errors in Version 5.711a, contrary to what TRC, the model developer, asserted.
- EPA's annotated in-code documentation identified several categories of changes, including:

- Bug fixes
- Non-optional technical enhancements
- Optional technical enhancements
- Non-technical enhancements
- Enhancement adjustments
- Coordinate conversion fixes

- EPA had serious technical concerns regarding how the optional technical enhancements, e.g., for mixing height, were implemented in CALMET.

The new approved Version 5.8 disables some of the VISTAS “optional technical enhancements”. Therefore, use of Version 5.756 or Version 6 of CALPUFF would appear to be inconsistent with the current EPA approved version. Default values of technical options specified in the newly approved version were adopted by ENSR.

Table 2-1 CALMET Options Comparison

Variable	Description	WRAP Value	ENSR Value
RMAX1	Maximum radius of influence over land in the surface layer	50	30
R1	Relative weighting of the first-guess field and observations in the surface layer	100	18
R2	Relative weighting of the first-guess field and observations in the layers aloft	200	20

Figure 2-2 CALMET Wind Fields with WRAP Settings

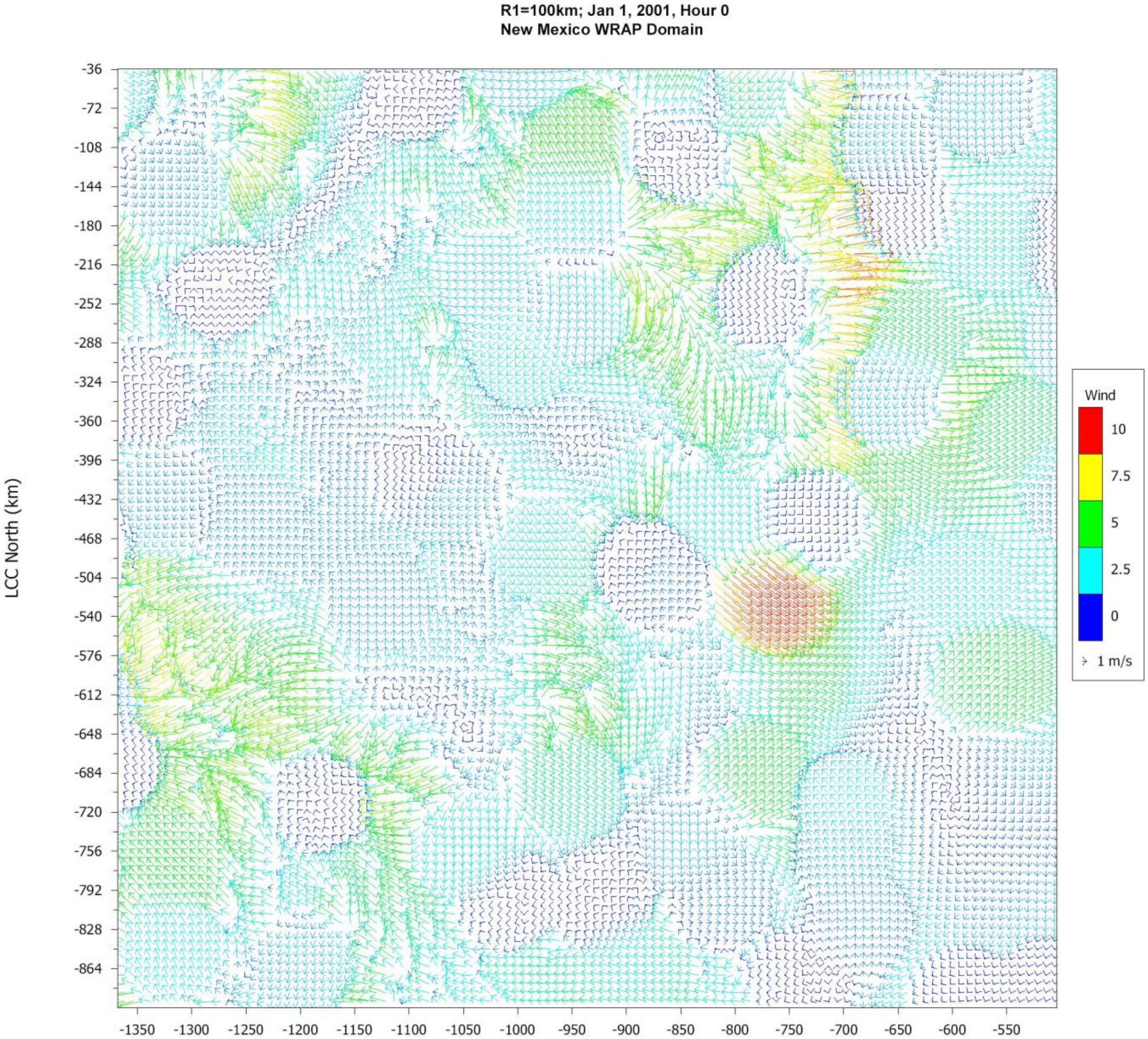
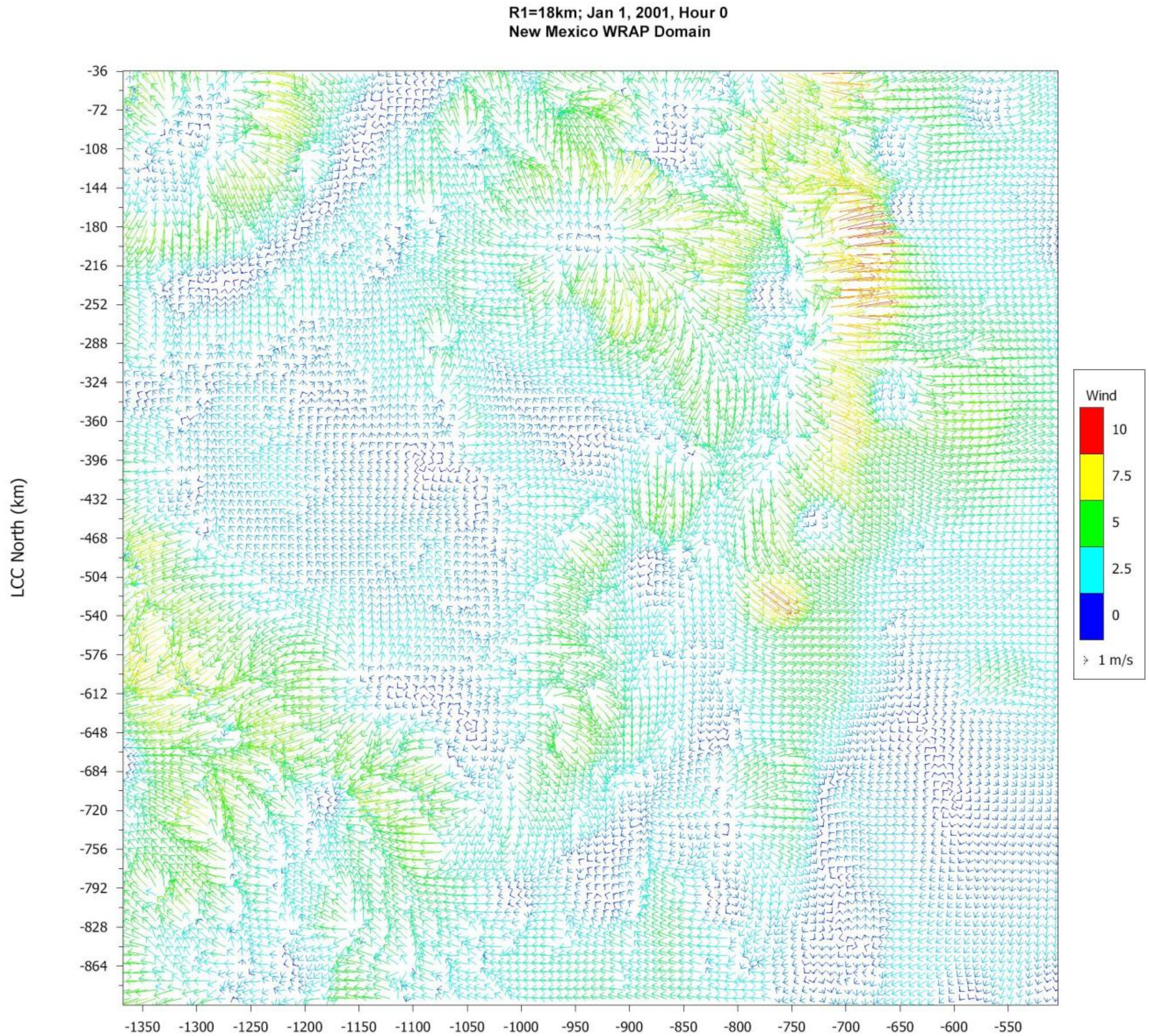


Figure 2-3 CALMET Wind Fields with ENSR Settings



2.3 IMPROVE Monitoring Network

The Visibility Information Exchange Web System (VIEWS) is an online database of air quality data designed to understand the effects of air pollution on visibility and to support the Regional Haze Rule enacted by the USEPA to reduce regional haze and improve visibility in national parks and wilderness areas (http://vista.cira.colostate.edu/views/).

The VIEWS database contains annual summary of Class I area-specific charts of visibility-degrading pollutants. Bar charts depict seasonal patterns of pollution and pie charts show the average composition for the 20% best and 20% worst pollution days. An example of a bar and pie chart for Mesa Verde National Park is shown in Figure 2-4. Mesa Verde is the closest Class I area to FCPP. Bar and pie charts for the modeled sixteen Class I areas for year 2002 are presented in Appendix A. Year 2002 was chosen because it is the year for which WRAP has established the baseline emissions inventory.

Figure 2-4 Plot of Measured Visibility-Degrading Pollutants in Mesa Verde NP, Year 2002

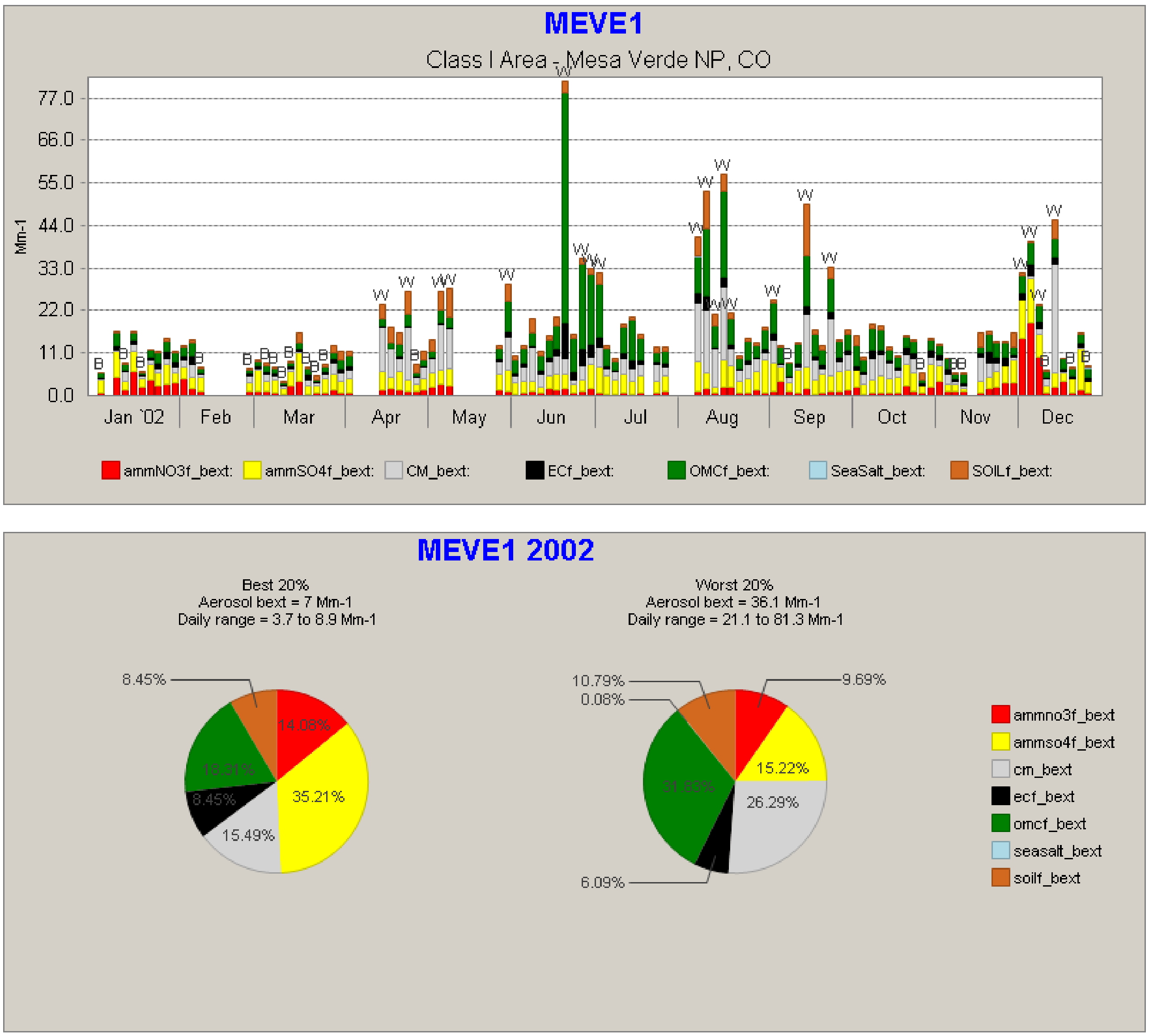


Figure 2-4 shows visibility degradation expressed as extinction in units of inverse megameters. Visibility is often described with two metrics: 1) visual range (the greatest distance that a large, dark object can be seen) or 2) light extinction coefficient (the attenuation of light per unit distance due to scattering and absorption by gases and particles in the atmosphere). Extinction coefficient (expressed in inverse distance units such as inverse megameters) can easily be apportioned into contributions by various particulate species, as is shown in Figure 2-4. The relationship between measured species concentrations and the extinction coefficient is known as the "IMPROVE equation". One drawback of visual range and extinction coefficient is that neither of them is linearly related to perceived visual scene changes caused by uniform haze. Therefore, a newly-developed visibility index, the deciview, or dv (Pitchford and Malm, 1994), has a scale that is linear to humanly-perceived changes in visual air quality. A one dv change is approximately a 10% change in the extinction coefficient, which is a small, but possibly perceptible scenic change (the threshold for perceived change is between 1 and 2 dv). In terms of extinction coefficient (bext) and visual range (vr), the deciview is:

$$\textbf{haziness } (\textbf{\textit{dv}}) = \textbf{10 ln (bext/0.01 km}^{-1}\textbf{) = 10 ln (391 km/vr)}$$

Figure 2-4 shows that organic aerosols (probably associated with forest fires for peak impacts) contribute about 32% and coarse particulate matter (due to wind-blown dust) contributes about 26% on the worst 20% days to the visibility extinction at Mesa Verde National Park. On the other hand, ammonium nitrate contributes only 10% and ammonium sulfate contributes 15% to the visibility extinction at the park, and these particles are due to emissions from all sources surrounding the park (including non-USA sources), not just from any individual source. Furthermore, the nitrate impacts were virtually nonexistent during the warm period of April-October (during the period of the heaviest park visitation), while sulfate impacts were generally present throughout the entire year. This pattern is generally present in all of the Class I areas, as can be seen in the composition plots shown in Appendix A. Due to this fact, NO_x emission controls are not very effective in improving regional haze. Moreover, certain NO_x emission controls, such as SCR and SNCR, create excess ammonia and primary sulfate emissions (H_2SO_4) that are both visibility-degrading, especially in the warm months when nitrates are a very small contributor to regional haze relative to sulfates.

3.0 CALPUFF Modeling Parameters

This section provides a summary of the modeling procedures that were used for the refined CALPUFF analysis conducted for the Four Corners Power Plant.

3.1 CALPUFF Modeling Domain and Receptors

The Four Corners Power Plant used the EPA-approved version of CALPUFF (Version 5.8, Level 070623) that has been posted at http://www.src.com/calpuff/download/download.htm#EPA_VERSION. Although the WRAP BART protocol mentions the use of CALPUFF version 6, the EPA's Office of Air Quality Planning and Standards has clearly stated that the use of a version other than the official EPA version is a non-guideline application that must obtain regional EPA approval on a case-by-case basis. It is clear from the discussion provided in Section 2.2 that CALPUFF version 6 is not approvable by EPA at this time without a significant effort to show that it is technically superior. To avoid the need for the justification and documentation required to use a non-guideline version of the model, ENSR used the official EPA version.

The extents of the 4-km WRAP domain for New Mexico are shown in Figure 3-1. The BART CALPUFF modeling for Four Corners was done using a smaller computational grid within the WRAP domain to minimize computation time and output file size. Four Corners computational grid domain is shown in Figure 3-1. This domain includes sixteen Class I areas within 300 km of the source, plus a 50-km buffer around each Class I area and a 100-km buffer around the source to assure puffs recirculation. The receptors used for each of the Class I areas are based on the National Park Service database of Class I receptors. For Grand Canyon and Maroon Bells Snowmass, only the receptors within the computational grid were included in CALPUFF modeling.

3.2 Technical Options Used in the Modeling

For CALPUFF model technical options, inputs and processing steps, APS followed the WRAP common BART protocol with the exception of the model version.

Due to the large distance to the nearest Class I area, building downwash effects were not included in the CALPUFF modeling.

WRAP has developed an hourly ozone measurements files for three years (2001-2003), available at http://pah.cert.ucr.edu/aqm/308/bart/calpuff/ozone_dat/. Data collection and processing are described in Section 3.1.2.7 of the WRAP protocol. These ozone data files were used as input to CALPUFF.

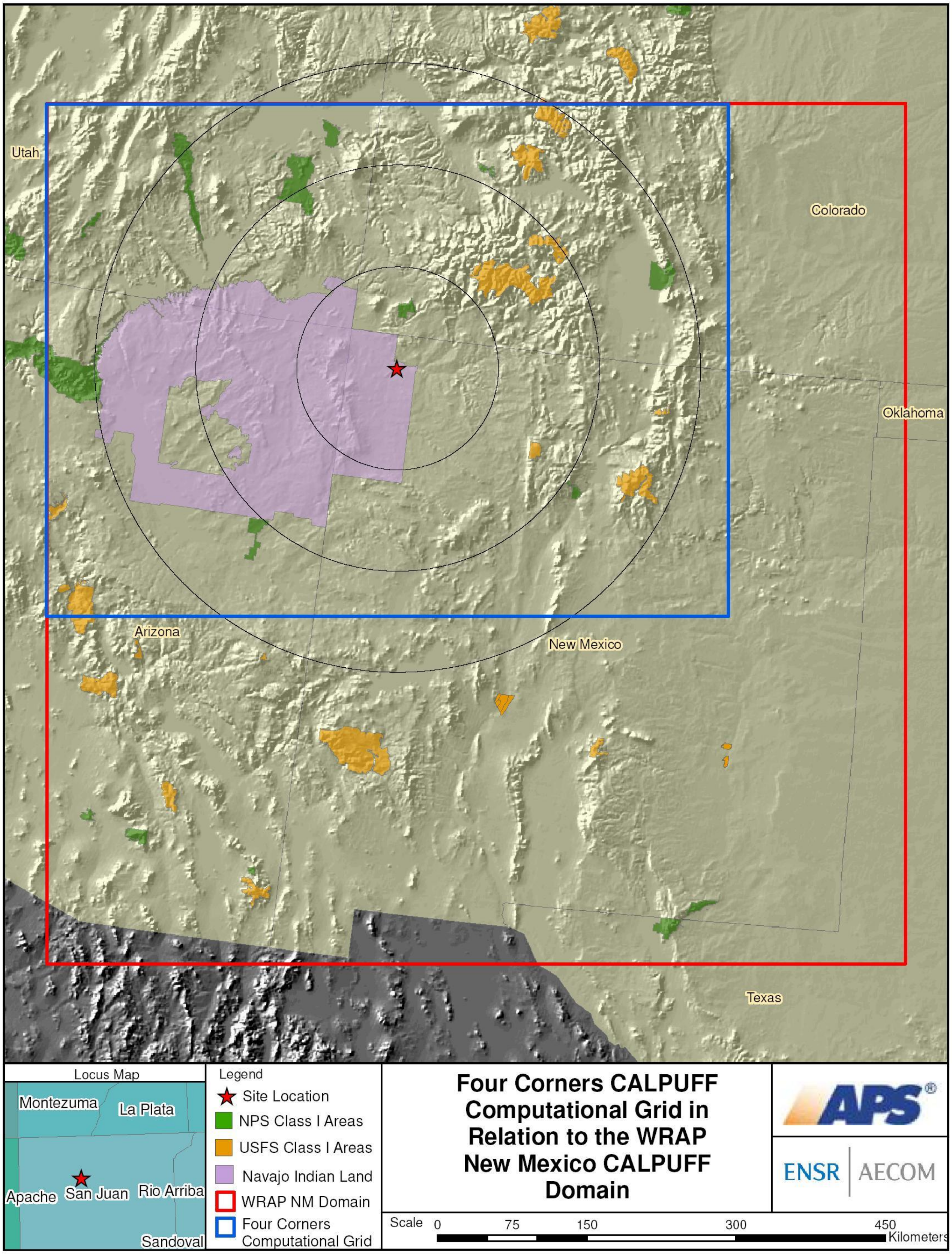
The POSTUTIL utility program was used to repartition HNO_3 and NO_3 using appropriate ammonia background values that were approved by the Federal Land Managers for the nearby Desert Rock Energy Facility (DREF) PSD permit application. For that project, located nearby in northwestern New Mexico, it was realized that the likely overprediction by CALPUFF of nitrates in winter can be partially addressed by using a monthly variation of background ammonia concentrations, with guidance from actual ammonia measurements, some of which were taken in the Grand Canyon. The default value of 1.0 ppb for arid lands as referenced in the IWAQM Phase 2 document is valid at 20 deg C, but the same document cites a strong dependence with ambient temperature, with variations of a factor of 3-4. This same dependence is seen at the CASTNET monitor at Bondville, Illinois (see page 5 at http://www.ladco.org/tech/monitoring/docs_gifs/NH3proposal-revised3.pdf). In addition, a study of light-affecting particles in SW Wyoming indicated that nitrates were overpredicted by a factor of 3 for a constant ammonia concentration of 1.0 ppb, and by a factor of 2 for an ammonia concentration of 0.5 ppb (see slide 57 at http://www.air.dnr.state.ga.us/airpermit/psd/dockets/longleaf/facilitydocs/050711_CALPUFF_eval.pdf). Since there are no large sources of ammonia due to agricultural activities near the Class I areas being analyzed (see Figure 1 in http://www.ladco.org/tech/monitoring/docs_gifs/ammonia_role_midwest_haze.pdf), it is appropriate to introduce a monthly varying ammonia background concentration to the CALPUFF modeling. Table 3-1 lists the values that were used in CALPUFF and have been agreed to by the National Park Service for DREF. Note that these values were used only for modeling the baseline and BART NOx Control Option 1 emissions. A refined set of ammonia background values was developed for modeling BART NOx Control Option 2 and 3 and further discussed in Section 4.3.

Table 3-1 Ambient Ammonia Background Concentration

Month	Ambient Ammonia Background Concentration (ppb)
January – February	0.2
March – April	0.5
May – September	1.0
October – November	0.5
December	0.2

These proposed values are consistent with the CMAQ modeled values provided in Appendix A of www.vistas-sesarm.org/BART/CMAQ2002_evaluation_Dec31_2005.pdf.

Figure 3-1 Four Corners CALPUFF Computational Grid in Relation to the WRAP NM Domain



3.3 Natural Conditions and Monthly f(RH) at Class I Areas

Sixteen Class I areas were modeled for the Four Corners Power Plant. For these Class I areas, natural background conditions must be established in order to determine a change in natural conditions related to a source's emissions. For the modeling described in this document, APS used the natural background light extinctions shown in Table 3-2, modified as noted below with site-specific considerations, and corresponding to the annual average (EPA 2003, Appendix B), consistent with the July 19, 2006 EPA guidance to Region 4 on this issue ("Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations", Joseph W. Paise/ EPA OAQPS to Kay Prince/Branch Chief).

Table 3-2 Background concentrations of soil used as input to CALPOST

Class I Area	Natural Background Concentrations (deciviews)	Natural Background non-Rayleigh Extinction (Mm^{-1})
Arches National Park	4.43	5.57
Bandelier Wilderness	4.46	5.62
Black Canyon of the Gunnison Wilderness	4.50	5.68
Canyonlands National Park	4.45	5.60
Capitol Reef National Park	4.47	5.64
Grand Canyon National Park	4.39	5.51
Great Sand Dunes National Monument	4.54	5.75
La Garita Wilderness	4.5	5.68
Maroon Bells Snowmass Wilderness	4.51	5.70
Mesa Verde National Park	4.53	5.73
Pecos Wilderness	4.48	5.65
Petrified Forest National Park	4.41	5.54
San Pedro Parks Wilderness	4.47	5.64
West Elk Wilderness	4.51	5.70
Weminuche Wilderness	4.5	5.68
Wheeler Peak Wilderness	4.51	5.70

To determine the input to CALPOST, it is first necessary to convert the deciviews to extinction using the equation:

Extinction (Mm^{-1}) = 10 exp(deciviews/10).

For example, for Bandelier, 4.46 deciviews is equivalent to an extinction of 5.62 inverse megameters (Mm^{-1}); this extinction excludes the default 10 Mm^{-1} for Rayleigh scattering. This remaining extinction is due to naturally occurring particles, and is held constant for the entire year's simulation. Therefore, the data provided to CALPOST for Bandelier would be the total natural background extinction minus 10 (expressed in Mm^{-1}), or 5.62. This is most easily input as a fine soil concentration of 5.62 $\mu g/m^3$ in CALPOST, since the extinction efficiency of soil (PM-fine) is 1.0 and there is no f(RH) component. The concentration entries for all other particle constituents would be set to zero, and the fine soil concentration would be kept the same for each month of the year.

The monthly values for f(RH) that CALPOST needs were taken from "Guidance for Tracking Progress Under the Regional Haze Rule" (EPA, 2003) Appendix A, Table A-3.

3.4 Light Extinction and Haze Impact Calculations

The CALPOST postprocessor was used for the calculation of the impact from the modeled source's primary and secondary particulate matter concentrations on light extinction. The formula that is used is the existing IMPROVE/EPA formula, which is applied to determine a change in light extinction due to increases in the particulate matter component concentrations. Using the notation of CALPOST, the formula is the following:

$$b_{ext} = 3\ f(RH)\ [(NH_4)2SO_4] + 3\ f(RH)\ [NH_4NO_3] + 4[OC] + 1[Soil] + 0.6[Coarse\ Mass] + 10[EC] + b_{Ray}$$

The concentrations, in square brackets, are in $\mu g/m^3$ and b_{ext} is in units of Mm^{-1}. The Rayleigh scattering term (b_{Ray}) has a default value of 10 Mm^{-1}, as recommended in EPA guidance for tracking reasonable progress (EPA, 2003a).

For assessment of visibility impacts at the Class I areas we used CALPOST Method 6. Each hour's source-caused extinction is calculated by first using the hygroscopic components of the source-caused concentrations, due to ammonium sulfate and nitrate, and monthly Class I area-specific f(RH) values. The contribution to the total source-caused extinction from ammonium sulfate and nitrate is then added to the other, non-hygroscopic components of the particulate concentration (from coarse and fine soil, secondary organic aerosols, and from elemental carbon) to yield the total hourly source-caused extinction.

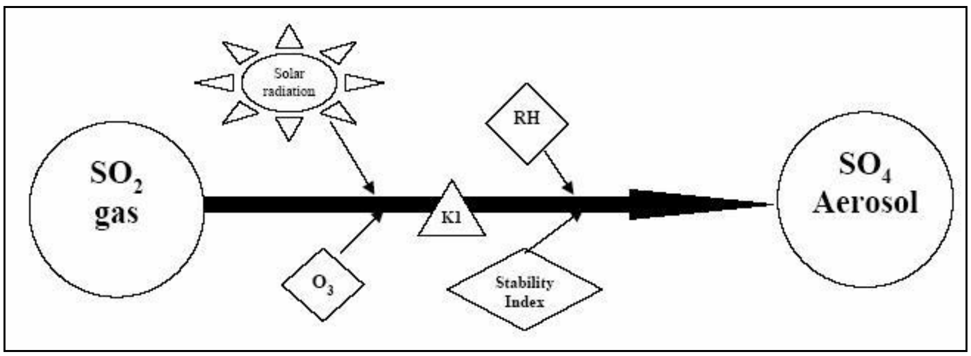
4.0 Factors Influencing Pollutant Emissions' Effects on Visibility

Secondary pollutants such as nitrates and sulfates are significant contributors to the visibility extinction in Class I areas. The CALPUFF model was used to determine the effect of these pollutants on Class I areas, associated with BART control options. CALPUFF uses the EPA-approved MESOPUFF II chemical reaction mechanism to convert SO_2 and NO_x emissions to secondary sulfates and nitrates. The discussion below describes how the secondary pollutants are formed and the factors affecting their formation.

4.1 Formation of Sulfates

The rate of transformation of gaseous SO_2 to ammonium sulfate $(NH_4)_2SO_4$ aerosol is dependent upon solar radiation, ambient ozone concentration, atmospheric stability, and relative humidity, as shown in Figure 4-1 (taken from the CALPUFF users guide, 2000). Homogeneous gas phase reaction is the dominant SO_2 oxidation pathway during clear, dry conditions (Calvert et al., 1978). CALPUFF assumes that the sulfate reacts preferentially with ammonia (NH_3) to form ammonium sulfate and that any remaining ammonia is available to form ammonium nitrate (NH_4NO_3).

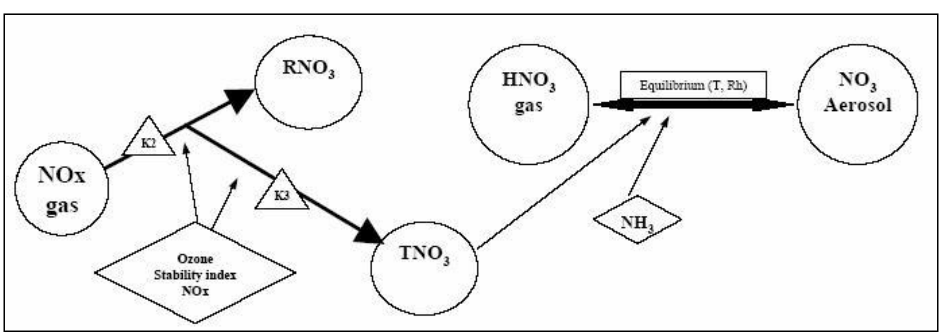
Figure 4-1 MESOPUFF II SO_2 Oxidation



4.2 Formation of Nitrates

The oxidation of NO_x to nitric acid (HNO_3) depends on the NO_x concentration, ambient ozone concentration, and atmospheric stability. Some of the nitric acid is then combined with available ammonia in the atmosphere to form ammonium nitrate aerosol in an equilibrium state that is a function of temperature, relative humidity, and ambient ammonia concentration, as shown in Figure 4-2 (from the CALPUFF users guide).

Figure 4-2 MESOPUFF II NO_x Oxidation

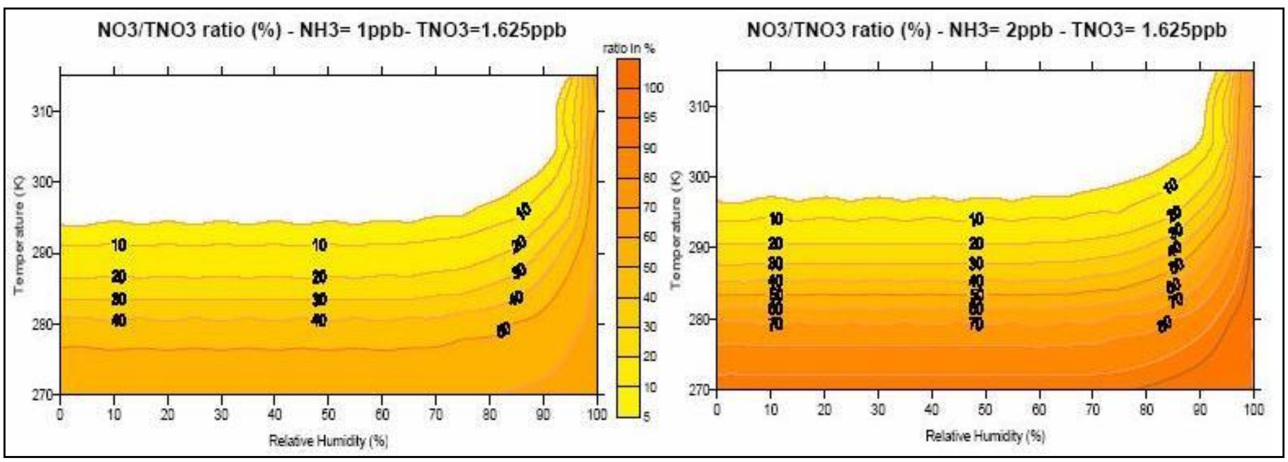


In CALPUFF, total nitrate ($TNO_3 = HNO_3 + NO_3$) is partitioned into each species according to the equilibrium relationship between gaseous HNO_3 and NO_3 aerosol. This equilibrium is a function of ambient temperature and relative humidity. Moreover, the formation of nitrate strongly depends on availability of NH_3 to form ammonium nitrate, as shown in Figure 4-3 (from CALPUFF courses given by TRC). The figure on the left shows that with 1 ppb of available ammonia and fixed temperature and humidity (for example, 275 deg K and 80% humidity), only 50% of the total nitrate forms particulate matter. When the available ammonia is increased to 2 ppb, as shown in the figure on the right, as much as 80% of the total nitrate is in the particulate form. Figure 4-3 also shows that colder temperatures and higher relative humidity significantly favor nitrate formation and vice versa. A summary of the conditions affecting nitrate formation are listed below:

- Colder temperature and higher relative humidity create favorable conditions to form nitrate particulate matter, and therefore <u>more</u> ammonium nitrate is formed;
- Warm temperatures and lower relative humidity create less favorable conditions to form nitrate particulate matter, and therefore <u>less</u> ammonium nitrate is formed;
- Sulfate preferentially scavenges ammonia over nitrates. In areas where sulfate concentrations are high and ambient ammonia concentrations are low, there is less ammonia available to react with nitrate, and therefore <u>less</u> ammonium nitrate is formed.

For this BART analysis, the effects of temperature and background ammonia concentrations on the nitrate formation are the key to understanding the effects of various NO_x control options. For parts of the country where sulfate concentrations are relatively high and ammonia emissions are quite low, the atmosphere is likely to be in an ammonia-limited regime relative to nitrate formation. Therefore, NO_x emission controls are not very effective in improving regional haze, especially if there is very little ambient ammonia available.

Figure 4-3 NO_3/HNO_3 Equilibrium Dependency on Temperature and Humidity



4.3 Refined Ambient Ammonia Background Concentrations

As discussed in Section 4.2, the formation of nitrate is highly sensitive to availability of ammonia to form ammonium nitrate. Ammonium nitrate is a visibility-degrading pollutant. For the purpose of evaluating NO_x emissions control options, the ambient ammonia background concentrations were refined to factor in excess ammonia emission increases associated with SNCR and SCR operations. Moreover, the installation of SCR creates primary sulfate emissions (H_2SO_4) that are also visibility-degrading.

Excess ammonia emissions associated with SNCR and SCR operations were modeled in CALPUFF to determine the 24-hour ammonia concentration at Mesa Verde National Park as well as the other Class I areas associated with a peak predicted impact from FCPP. Predicted excess ammonia concentrations associated with SNCR and SCR operation are listed in Table 4-1. For simplicity in the post-processing, the predicted values of additional ambient ammonia concentrations were allocated to three specific values covering the range of the CALPUFF predictions.   It is noteworthy from a review of the values listed in Table 4-1 that the highest additional ammonia concentration occurs at Mesa Verde National Park, while substantially lower concentrations are added at the more distant Class I areas.

The resultant ammonia concentrations for the peak daily impact at the Class I areas (corresponding to a peak regional haze event) were added to the monthly ambient background values, as shown in Table 4-1. Then POSTUTIL program (CALPUFF post-processor) was used to re-compute regional haze impacts with the adjusted ammonia background at each Class I areas.

Table 4-1 Refined Ambient Ammonia Background Concentration

<table>
<tr><th rowspan="2">Class I Area</th><th>SNCR</th><th>SCR</th></tr>
<tr><th>ppb</th><th>ppb</th></tr>
<tr><td colspan="3">These NH_3 values were predicted at each Class I area</td></tr>
<tr><td>Arches National Park</td><td>0.05</td><td>0.02</td></tr>
<tr><td>Bandelier Wilderness</td><td>0.04</td><td>0.01</td></tr>
<tr><td>Black Canyon of the Gunnison Wilderness</td><td>0.02</td><td>0.01</td></tr>
<tr><td>Canyonlands National Park</td><td>0.08</td><td>0.03</td></tr>
<tr><td>Capitol Reef National Park</td><td>0.03</td><td>0.01</td></tr>
<tr><td>Grand Canyon National Park</td><td>0.02</td><td>0.01</td></tr>
<tr><td>Great Sand Dunes National Monument</td><td>0.02</td><td>0.01</td></tr>
<tr><td>La Garita Wilderness</td><td>0.02</td><td>0.01</td></tr>
<tr><td>Mesa Verde National Park</td><td>0.19</td><td>0.08</td></tr>
<tr><td>Pecos Wilderness</td><td>0.03</td><td>0.01</td></tr>
<tr><td>Petrified Forest National Park</td><td>0.03</td><td>0.01</td></tr>
<tr><td>San Pedro Parks Wilderness</td><td>0.08</td><td>0.03</td></tr>
<tr><td>West Elk Wilderness</td><td>0.02</td><td>0.01</td></tr>
<tr><td>Weminuche Wilderness</td><td>0.06</td><td>0.02</td></tr>
<tr><td>Wheeler Peak Wilderness</td><td>0.02</td><td>0.01</td></tr>
<tr><td>Maroon Bells Snowmass Wilderness</td><td>0.01</td><td>0.004</td></tr>
<tr><td colspan="3">Color-coded NH_3 values were averaged and then added to the monthly ambient NH_3 concentrations</td></tr>
<tr><td>Mesa Verde National Park</td><td>0.19</td><td>0.08</td></tr>
<tr><td>Arches National Park</td><td rowspan="5">0.06</td><td rowspan="15">0.01</td></tr>
<tr><td>Bandelier Wilderness</td></tr>
<tr><td>Canyonlands National Park</td></tr>
<tr><td>San Pedro Parks Wilderness</td></tr>
<tr><td>Weminuche Wilderness</td></tr>
<tr><td>Black Canyon of the Gunnison Wilderness</td><td rowspan="10">0.02</td></tr>
<tr><td>Capitol Reef National Park</td></tr>
<tr><td>Grand Canyon National Park</td></tr>
<tr><td>Great Sand Dunes National Monument</td></tr>
<tr><td>La Garita Wilderness</td></tr>
<tr><td>Pecos Wilderness</td></tr>
<tr><td>Petrified Forest National Park</td></tr>
<tr><td>West Elk Wilderness</td></tr>
<tr><td>Wheeler Peak Wilderness</td></tr>
<tr><td>Maroon Bells Snowmass Wilderness</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Excess NH_3 Emission Rate (lb/hr)</td><td>70.71</td><td>28.28</td></tr>
</table>

5.0 BART Eligibility Analysis

5.1 BART-Eligible Requirements

The BART-affected emission units at the Four Corners plant are Units 1 through 5. Each of the units were in existence on August 7, 1977 and had not been in operation for more than 15 years as of that date. Therefore, they fall into the time period addressed by the Regional Haze BART Rule published on July 6, 2005. In addition, the units meet the other criteria for BART eligibility. All five units burn western bituminous coal. NO_x presumptive BART limits apply to FCPP Units 3-4-5 (0.39 lb/MMBtu for Unit 3 and 0.40 lb/MMBtu for Units 4-5) since the plant capacity exceeds 750 MW, and these units all exceed 200 MW. NO_x presumptive BART limits do not apply to Units 1-2 since they do not exceed 200 MW.

5.2 Existing Control Equipment and Emission Rates

The air emissions data used to assess the visibility impacts associated with the Four Corners Power Plant at the selected Class I areas are discussed in this section. The SO_2, NO_x and PM_{10} baseline emissions were provided by APS for the baseline calendar years, 2002 through 2006. The baseline emissions were based on the highest daily emission rates of these pollutants and highest daily heat input rates for the baseline period.

Baseline SO_2 emissions were based on the highest daily emission rates and highest daily heat input rates compiled by the continuous emissions monitoring system (CEMS) during 2005 through 2006, since the plant operations were changed during 2004 to incorporate a higher level of removal of SO_2 emissions. Based on a review of the CEMS data, the highest daily SO_2 emissions were determined by excluding a few days for which there were documented startups, shutdowns, or malfunctions that affected the SO_2 emission rates. Baseline NO_x emissions were based on the highest daily emission rates and highest daily heat input rates compiled by the CEMS during 2002 through 2006, since the plant operations relative to NO_x emissions have not recently changed. No data were excluded due to startups, shutdowns, and malfunctions from the determination of baseline NO_x emissions. Due to the assumption of these worst-case emissions for each day of the 3-year simulation, the modeling approach prescribed by EPA's BART rule is very conservative, and will likely result in an overprediction of the 98^{th} percentile impact.

Baseline PM emissions were based on the highest filterable PM emissions determined by annual stack testing and highest daily heat input rates compiled by the CEMS during 2002 through 2006. Because various components of PM_{10} emissions have different visibility extinction efficiencies, the PM_{10} emissions are divided or "speciated" into several components. Four Corners is using, where available, source-specific emission and speciation factors. Otherwise, default values from EPA's AP-42 reference document are used to determine emissions and speciation.

Units 1 through 3 at the Four Corners Power Plant are wall-fired, dry-bottom pulverized coal-fired boilers equipped with venturi scrubbers for PM and SO_2 control, while Units 4 and 5 are cell burner, pulverized coal-fired boilers equipped with lime spray towers and baghouses for SO_2 and PM control. The exhaust gases from Units 1 and 2 and Units 4 and 5 are ducted into two separate stacks each containing two flues. The Unit 3 exhaust gas is ducted into a separate stack. Table 5-1 summarizes exhaust stack parameters that were used to model the baseline conditions and the BART control options. Table 5-2 summarizes baseline emissions.

Total PM_{10} is comprised of filterable and condensable emissions. The PM_{10} emissions and speciation approach to be used for the modeling described in this protocol is presented below.

- Baseline filterable PM emissions (units of lb/hr) were based on the source-specific emission factors (units of lb/MMBtu) derived from annual stack tests and the maximum daily heat input recorded by the CEMS during the 2002 through 2006 period.

- Based on AP-42 Table 1.1-6 (September 1998), 71% of filterable PM is PM_{10} and 51% is fine PM_{10} for a dry-bottom boiler firing pulverized coal with a scrubber for PM control (Units 1, 2 and 3). In addition, 92% of filterable PM is PM_{10} and 53% of fine PM_{10} for a dry-bottom boiler firing pulverized coal with a fabric filter for PM control (Units 4 and 5).
- Elemental carbon is 3.7% of fine PM based on the best estimate for electric utility coal combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.
- Total condensable PM_{10} is the sum of H_2SO_4 and organic condensable PM_{10} emissions.
- H_2SO_4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H_2SO_4 emissions are determined from "(Q)(98.06/64.04)(F1)(F2)" where Q is the uncontrolled SO_2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater and 0.65 for a venturi scrubber).
- Based on AP-42, Table1.1-5 (September 1998), organic condensable PM_{10} is 0.004 lb/MMBtu for boilers firing pulverized coal with FGD for SO_2 control.

Table 5-1 Modeling Exhaust Stack Parameters

	Units	Units 1-2 Merged Stacks	Unit 3 Single Stack	Units 4-5 Merged Stacks
UTM-X, Zone 12, NAD83	Meters	724966.054	724966.045	725349.264
UTM-Y, Zone 12, NAD83	Meters	4063508.296	4063433.039	4063085.953
Stack Height	Meters	75.90	76.20	93.73
Base Elevation	Meters	1625.50	1625.27	1631.29
Effective Diameter	Meters	6.47	4.57	12.28
Gas Exit Velocity	m/s	20.73	23.77	19.21
Stack Gas Exit Temperature	deg K	323.15	323.15	325.93

Table 5-2 Baseline Emission Rates

Unit	Description	Max. Heat Input	Higher Heating Value	Fuel Sulfur Content	Maximum NOx Emissions		Maximum SO2 Emissions		Maximum Filterable PM Emissions			Filterable PM10					Condensable PM10			Total PM10
												total	coarse	Fine			total	SO4	organic	
														fine total	fine soil	EC				
		MMBtu/hr (a)	Btu/lb (b)	% wt. (b)	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	Basis	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
1	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	2,087	8,880	0.772	0.882	1,841.37	0.222	464.17	0.030	62.60	Stack Test	44.45 (d)	12.52	31.9 (d)	30.74	1.18 (f)	10.59	2.24 (g)	8.35 (i)	55.03
2	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	2,352	8,880	0.772	0.666	1,567.66	0.262	615.12	0.041	97.46	Stack Test	69.20 (d)	19.49	49.7 (d)	47.87	1.84 (f)	11.94	2.53 (g)	9.41 (i)	81.13
3	Bituminous Coal, 253 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	2,896	8,880	0.772	0.665	1,926.23	0.344	995.26	0.037	107.72	Stack Test	76.48 (d)	21.54	54.9 (d)	52.90	2.03 (f)	14.69	3.11 (g)	11.58 (i)	91.17
4	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	8,000	8,880	0.772	0.627	5,015.98	0.253	2,026.10	0.025	197.75	Stack Test	181.926 (e)	77.12	104.81 (e)	100.93	3.88 (f)	32.60	0.60 (h)	32.00 (i)	214.53
5	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	8,047	8,880	0.772	0.552	4,444.04	0.265	2,130.76	0.012	94.04	Stack Test	86.515 (e)	36.67	49.84 (e)	48.00	1.84 (f)	32.79	0.61 (h)	32.19 (i)	119.31

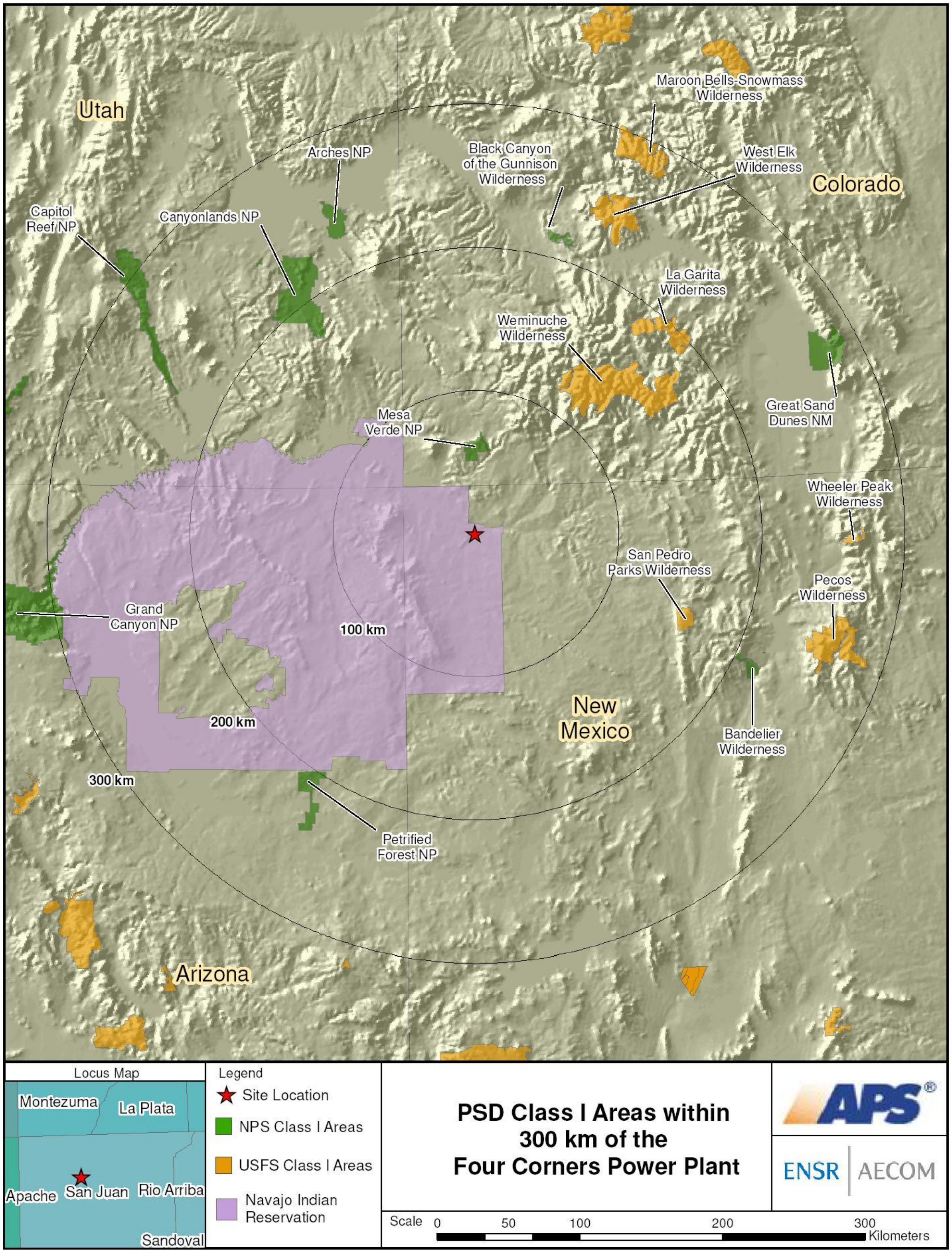
(a) Maximum heat input rate are based worst-case daily emissions for calendar years 2002 through 2006.
(b) Higher heating values and sulfur content are based on the average values for calendar years 2002 through 2006.
(c) Baseline NOx, SO2 and filterable PM emissions are based worst-case daily emissions received on March 2, 2007 and revised April 26, 2007.
(d) For a dry bottom boiler fired with bituminous coal and equipped with a scrubber, total filterable PM10 is 71% of filterable PM and fine filterable PM10 is 51% of filterable PM based on AP-42, Table 1.1-6.
(e) For a dry bottom boiler fired with bituminous coal and equipped with a bagouse, total filterable PM10 is 92% of filterable PM and fine filterable PM10 is 53% of filterable PM based on AP-42, Table 1.1-6.
(f) Elemental carbon is 3.7% of fine PM based on the best estimate for electric utility coal combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.
(g) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater and 0.65 for a venturi scrubber).
(h) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1+S2)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater, 0.40 for a wet spray tower, and 0.10 for a baghouse).
(i) For pulverized coal-fired boilers with an FGD system, total condensable organic PM10 emissions factor is 0.004 lb/MMBtu based on AP-42, Table 1.1-5.

5.3 Affected Class I Areas

Figure 5-1 shows a plot of the Four Corners Power Plant relative to nearby Class I areas. There are sixteen Class I areas within 300 km of the plant. They are:

1. Arches National Park
2. Bandelier Wilderness
3. Black Canyon of the Gunnison Wilderness
4. Canyonlands National Park
5. Capitol Reef National Park
6. Grand Canyon National Park
7. Great Sand Dunes National Monument
8. La Garita Wilderness
9. Maroon Bells Snowmass Wilderness
10. Mesa Verde National Park
11. Pecos Wilderness
12. Petrified Forest National Park
13. San Pedro Parks Wilderness
14. West Elk Wilderness
15. Weminuche Wilderness
16. Wheeler Peak Wilderness

Figure 5-1 Location of Class I Areas in Relation to the Four Corners Power Plant



5.4 Baseline CALPUFF Modeling Results

CALPUFF modeling results of the baseline emissions at sixteen Class I areas are presented in Table 5-3 and graphically plotted in Figure 5-2. Modeling was conducted for all three years of CALMET meteorological data (2001-2003).

For each Class I area and year, Table 5-3 lists the 8th highest delta-deciview. Figure 5-2 shows the total 8th highest deciview impacts. The figure indicates that the higher visibility impacts generally occur at Mesa Verde National Park, San Pedro Parks Wilderness, and Canyonlands National Park. Higher impacts at these Class I areas are due to their proximity to FCPP.

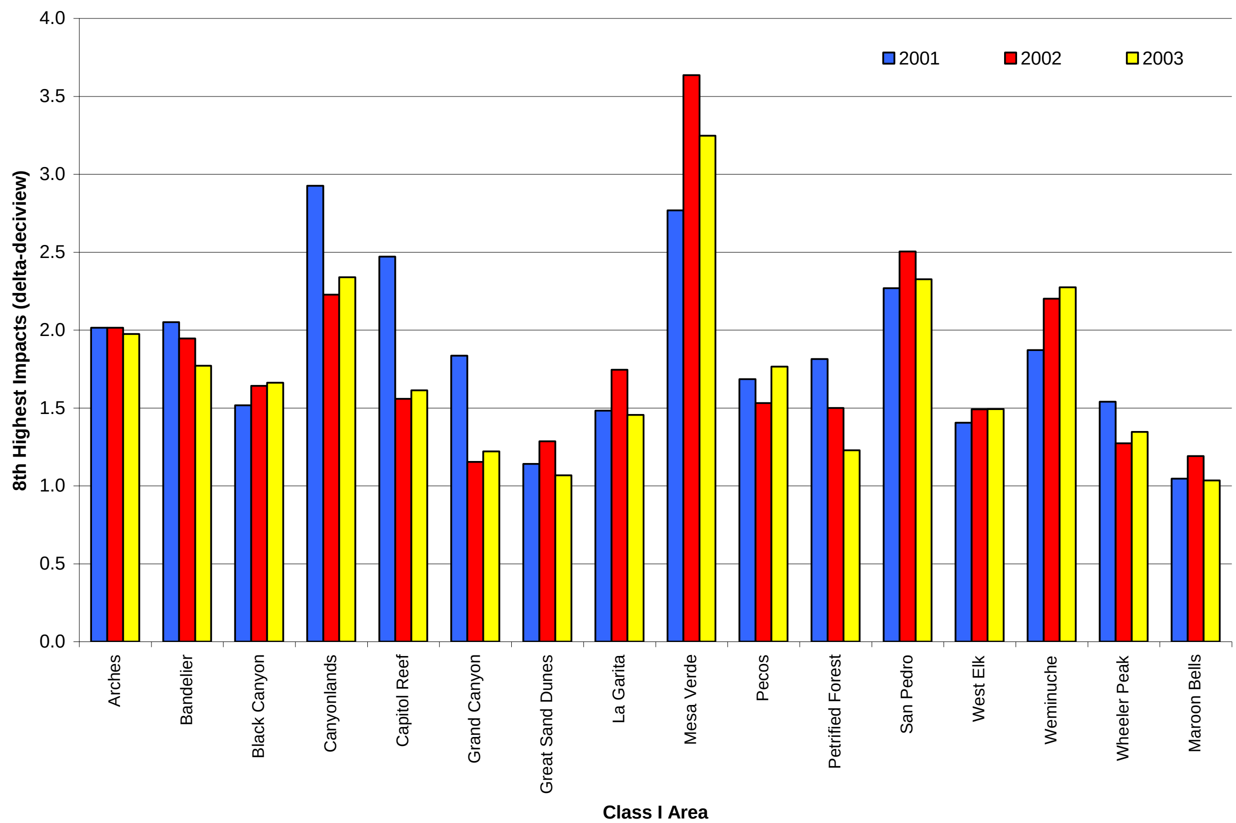
EPA recommends in their BART rule that the 98th percentile value of the modeling results should be compared to the threshold of 0.5 deciviews to determine if a source contributes to visibility impairment. This statistic is also recommended for comparing visibility improvements due to BART control options. On an annual basis, this implies the 8th highest day at each modeled Class I area.

The results of the baseline emissions indicate that Four Corners units are subject to BART review because the predicted visibility impacts exceed 0.5 deciviews in at least one Class I area. Therefore, BART determination modeling was conducted for specific NO_x and PM control options discussed in Section 6. The results of the modeling are discussed in Section 6.2.

Table 5-3 Regional Haze Impacts Due to Baseline Emissions

Class I Area	Met Year 2001	Met Year 2002	Met Year 2003
	8th Highest Δ dv	8th Highest Δ dv	8th Highest Δ dv
Arches National Park	2.02	2.01	1.97
Bandelier Wilderness	2.05	1.95	1.77
Black Canyon of the Gunnison Wilderness	1.52	1.64	1.66
Canyonlands National Park	2.93	2.23	2.34
Capitol Reef National Park	2.47	1.56	1.61
Grand Canyon National Park	1.84	1.15	1.22
Great Sand Dunes National Monument	1.14	1.29	1.07
La Garita Wilderness	1.48	1.75	1.46
Mesa Verde National Park	2.77	3.64	3.25
Pecos Wilderness	1.68	1.53	1.76
Petrified Forest National Park	1.81	1.50	1.23
San Pedro Parks Wilderness	2.27	2.50	2.33
West Elk Wilderness	1.41	1.49	1.49
Weminuche Wilderness	1.87	2.20	2.27
Wheeler Peak Wilderness	1.54	1.27	1.35
Maroon Bells Snowmass Wilderness	1.05	1.19	1.03

Figure 5-2 8th Highest Regional Haze Impacts for Each Modeled Year Due to Baseline Emissions



6.0 BART Control Options Modeling Analysis

This section provides a summary of the modeled visibility improvement as a result of installing BART control options on FCPP Units 1 - 5.

6.1 Modeled Control Scenarios

One PM_{10} and three NO_x BART control scenarios were modeled for each meteorological year (2001-2003) and the seven closest Class I areas (considered here due to their proximity to the FCPP). The BART control options are listed below.

PM_{10} Control Option 1: fabric filter (baghouse) controls on units 1, 2, and 3. Table 6-1 lists emission rates associated with these PM_{10} controls.

NO_x Control Option 1: Advanced combustion controls, such as low NO_x burners (LNB) on Units 1-5 and overfire furnace air (OFA) on Units 3-5.

- Overfire Furnace Air (OFA) technology involves the introduction of combustion air that is separated into primary and secondary flow sections to achieve complete burnout and to encourage the formation of N_2 rather than NO_x.
- Low NO_x burners (LNB) are designed to control fuel and air mixing at each burner in order to create larger and more branched flames. This internal combustion staging reduces peak flame temperature and results in less NO_x formation.

Table 6-2 lists emission rates associated with these NO_x controls.

NO_x Control Option 2: Advanced combustion controls (LNB/OFA) on Units 1-5 in combination with High Energy Reagent Technology (HERT) on Units 1-3 and selective non-catalytic reduction (SNCR) on Units 4-5.

- HERT technology involves OFA coupled with reagent injection to control nitrogen oxide emissions. The OFA system stages combustion for an initial reduction and a high energy chemical agent follows the OFA into the proper temperature window to optimize the NO_x conversion. The advantage of HERT over SNCR is that fewer injectors are required than for a typical SNCR system.
- SNCR is based on a gas-phase homogeneous reaction that involves the injection of an amine-based compound into the flue gas within an appropriate temperature for reduction of NO_x.

Table 6-3 lists emission rates associated with these NO_x controls.

NO_x Control Option 3: Advanced combustion controls (LNB/OFA) in combination with selective catalytic reduction (SCR) on Units 1-5.

- SCR reduction is a process that involves post-combustion removal of NO_x from flue gas utilizing a catalytic reactor. In the SCR process, ammonia injected into the flue gas reacts with nitrogen oxides and oxygen to form nitrogen and water vapor.

Table 6-4 lists emission rates associated with these NO_x controls.

Table 6-1 PM10 BART Control Option 1

Unit	Description	New BART Controls	Percent NOx Control	Percent PM Control	Max. Heat Input	Higher Heating Value	Fuel Sulfur Content	Maximum NOx Emissions		Maximum SO2 Emissions		Maximum Filterable PM Emissions			Filterable PM10					Condensable PM10			Total PM10
															total	coarse	Fine						
																	fine total	fine soil	EC	total	SO4	organic	
					MMBtu/hr (a)	Btu/lb (b)	% wt. (b)	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	Basis	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
1	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, FF, Venturi Scrubber, Wet FGD	FF	0%	52%	2,087	8,880	0.772	0.882	1,841.37	0.222	464.17	0.014	30.05	Stack Test	27.64 (d)	11.72	15.9 (d)	15.34	0.59 (f)	8.57	0.22 (g)	8.35 (i)	36.21
2	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, FF, Venturi Scrubber, Wet FGD	FF	0%	59%	2,352	8,880	0.772	0.666	1,567.66	0.262	615.12	0.017	39.96	Stack Test	36.76 (d)	15.58	21.2 (d)	20.39	0.78 (f)	9.66	0.25 (g)	9.41 (i)	46.42
3	Bituminous Coal, 253 MW, PC Wall-Fired, Dry Bottom, FF, Venturi Scrubber, Wet FGD	FF	0%	59%	2,896	8,880	0.772	0.665	1,926.23	0.344	995.26	0.015	44.16	Stack Test	40.63 (d)	17.22	23.4 (d)	22.54	0.87 (f)	11.89	0.31 (g)	11.58 (i)	52.52
4	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	None	0%	0%	8,000	8,880	0.772	0.627	5,015.98	0.253	2,026.10	0.025	197.75	Stack Test	181.926 (e)	77.12	104.81 (e)	100.93	3.88 (f)	32.60	0.60 (h)	32.00 (i)	214.53
5	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	None	0%	0%	8,047	8,880	0.772	0.552	4,444.04	0.265	2,130.76	0.012	94.04	Stack Test	86.515 (e)	36.67	49.84 (e)	48.00	1.84 (f)	32.79	0.61 (h)	32.19 (i)	119.31

(a) Maximum heat input rate are based worst-case daily emissions for calendar years 2002 through 2006.
(b) Higher heating values and sulfur content are based on the average values for calendar years 2002 through 2006.
(c) Baseline NOx, SO2 and filterable PM emissions are based worst-case daily emissions received on March 2, 2007 and revised April 26, 2007.
(d) For a dry bottom boiler fired with bituminous coal and equipped with a scrubber, total filterable PM10 is 71% of filterable PM and fine filterable PM10 is 51% of filterable PM based on AP-42, Table 1.1-6.
(e) For a dry bottom boiler fired with bituminous coal and equipped with a bagouse, total filterable PM10 is 92% of filterable PM and fine filterable PM10 is 53% of filterable PM based on AP-42, Table 1.1-6.
(f) Elemental carbon is 3.7% of fine PM based on the best estimate for electric utility coal combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.
(g) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1+S2)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater,0.65 for a venturi scrubber, and 0.10 for a bahouse).
(h) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1+S2)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater, 0.40 for a wet spray tower, and 0.10 for a baghouse).
(i) For pulverized coal-fired boilers with an FGD system, total condensable organic PM10 emissions factor is 0.004 lb/MMBtu based on AP-42, Table 1.1-5.

Table 6-2 NO_x BART Control Option 1 (OFA/LNB)

Unit	Description	New NOx BART Controls	Percent NOx Control	Max. Heat Input	Higher Heating Value	Fuel Sulfur Content	Maximum NOx Emissions		Maximum SO2 Emissions		Maximum Filterable PM Emissions			Filterable PM10					Condensable PM10			Total PM10
														total	coarse	Fine						
																fine total	fine soil	EC	total	SO4	organic	
				MMBtu/hr (a)	Btu/lb (b)	% wt. (b)	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	Basis	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
1	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB	45%	2,087	8,880	0.772	0.484	1,010.91	0.222	464.17	0.030	62.60	Stack Test	44.45 (d)	12.52	31.9 (d)	30.74	1.18 (f)	10.59	2.24 (g)	8.35 (i)	55.03
2	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB	33%	2,352	8,880	0.772	0.447	1,051.90	0.262	615.12	0.041	97.46	Stack Test	69.20 (d)	19.49	49.7 (d)	47.87	1.84 (f)	11.94	2.53 (g)	9.41 (i)	81.13
3	Bituminous Coal, 253 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB, OFA	44%	2,896	8,880	0.772	0.373	1,078.69	0.344	995.26	0.037	107.72	Stack Test	76.48 (d)	21.54	54.9 (d)	52.90	2.03 (f)	14.69	3.11 (g)	11.58 (i)	91.17
4	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	LNB, OFA	29%	8,000	8,880	0.772	0.445	3,561.35	0.253	2,026.10	0.025	197.75	Stack Test	181.926 (e)	77.12	104.81 (e)	100.93	3.88 (f)	32.60	0.60 (h)	32.00 (i)	214.53
5	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	LNB, OFA	29%	8,047	8,880	0.772	0.392	3,155.27	0.265	2,130.76	0.012	94.04	Stack Test	86.515 (e)	36.67	49.84 (e)	48.00	1.84 (f)	32.79	0.61 (h)	32.19 (i)	119.31

(a) Maximum heat input rate are based worst-case daily emissions for calendar years 2002 through 2006.
(b) Higher heating values and sulfur content are based on the average values for calendar years 2002 through 2006.
(c) Baseline NOx, SO2 and filterable PM emissions are based worst-case daily emissions received on March 2, 2007 and revised April 26, 2007.
(d) For a dry bottom boiler fired with bituminous coal and equipped with a scrubber, total filterable PM10 is 71% of filterable PM and fine filterable PM10 is 51% of filterable PM based on AP-42, Table 1.1-6.
(e) For a dry bottom boiler fired with bituminous coal and equipped with a bagouse, total filterable PM10 is 92% of filterable PM and fine filterable PM10 is 53% of filterable PM based on AP-42, Table 1.1-6.
(f) Elemental carbon is 3.7% of fine PM based on the best estimate for electric utility coal combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.
(g) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1+S2)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater and 0.65 for a venturi scrubber).
(h) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1+S2)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater, 0.40 for a wet spray tower, and 0.10 for a baghouse).
(i) For pulverized coal-fired boilers with an FGD system, total condensable organic PM10 emissions factor is 0.004 lb/MMBtu based on AP-42, Table 1.1-5.

Table 6-3 NO_x BART Control Option 2 (OFA/LNB/HERT/SNCR)

Unit	Description	New NOx BART Controls	Percent NOx Control	Max. Heat Input	Higher Heating Value	Fuel Sulfur Content	Maximum NOx Emissions		Maximum SO2 Emissions		Maximum Filterable PM Emissions			Filterable PM10					Condensable PM10			Total PM10	NH3 Slip
														total	coarse	Fine			total	SO4	organic		
																fine total	fine soil	EC					
				MMBtu/hr (a)	Btu/lb (b)	% wt. (b)	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	Basis	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
1	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB, OFA, HERT	74%	2,087	8,880	0.772	0.229	478.76	0.222	464.17	0.030	62.60	Stack Test	44.45 (d)	12.52	31.9 (d)	30.74	1.18 (f)	10.59	2.24 (g)	8.35 (i)	55.03	6.31 (j)
2	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB, OFA, HERT	69%	2,352	8,880	0.772	0.207	485.98	0.262	615.12	0.041	97.46	Stack Test	69.20 (d)	19.49	49.7 (d)	47.87	1.84 (f)	11.94	2.53 (g)	9.41 (i)	81.13	7.11 (j)
3	Bituminous Coal, 253 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB, OFA, HERT	66%	2,896	8,880	0.772	0.226	654.92	0.344	995.26	0.037	107.72	Stack Test	76.48 (d)	21.54	54.9 (d)	52.90	2.03 (f)	14.69	3.11 (g)	11.58 (i)	91.17	8.76 (j)
4	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	LNB, OFA, SNCR	47%	8,000	8,880	0.772	0.332	2,658.47	0.253	2,026.10	0.025	197.75	Stack Test	181.926 (e)	77.12	104.81 (e)	100.93	3.88 (f)	32.60	0.60 (h)	32.00 (i)	214.53	24.19 (j)
5	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	LNB, OFA, SNCR	47%	8,047	8,880	0.772	0.293	2,355.34	0.265	2,130.76	0.012	94.04	Stack Test	86.515 (e)	36.67	49.84 (e)	48.00	1.84 (f)	32.79	0.61 (h)	32.19 (i)	119.31	24.33 (j)

(a) Maximum heat input rate are based worst-case daily emissions for calendar years 2002 through 2006.
(b) Higher heating values and sulfur content are based on the average values for calendar years 2002 through 2006.
(c) Baseline NOx, SO2 and filterable PM emissions are based worst-case daily emissions received on March 2, 2007 and revised April 26, 2007.
(d) For a dry bottom boiler fired with bituminous coal and equipped with a scrubber, total filterable PM10 is 71% of filterable PM and fine filterable PM10 is 51% of filterable PM based on AP-42, Table 1.1-6.
(e) For a dry bottom boiler fired with bituminous coal and equipped with a bagouse, total filterable PM10 is 92% of filterable PM and fine filterable PM10 is 53% of filterable PM based on AP-42, Table 1.1-6.
(f) Elemental carbon is 3.7% of fine PM based on the best estimate for electric utility coal combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.
(g) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater and 0.65 for a venturi scrubber).
(h) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), and F2 is the control factor (0.56 for an air preheater, 0.40 for a wet spray tower, and 0.10 for a baghouse).
(i) For pulverized coal-fired boilers with an FGD system, total condensable organic PM10 emissions factor is 0.004 lb/MMBtu based on AP-42, Table 1.1-5.
(j) Ammonia slip is 5.00 ppmvd at 6% O2 for SNCR.

Table 6-4 NO_x BART Control Option 3 (OFA/LNB/SCR)

Unit	Description	New NOx BART Controls	Percent NOx Control	Max. Heat Input	Higher Heating Value	Fuel Sulfur Content	Maximum NOx Emissions		Maximum SO2 Emissions		Maximum Filterable PM Emissions			Filterable PM10					Condensable PM10			Total PM10	NH3 Slip
														total	coarse	Fine			total	SO4	organic		
																fine total	fine soil	EC					
				MMBtu/hr (a)	Btu/lb (b)	% wt. (b)	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	lb/MMBtu (c)	lb/hr	Basis	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
1	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB, OFA, SCR	92%	2,087	8,880	0.772	0.071	147.31	0.222	464.17	0.030	62.60	Stack Test	44.45 (d)	12.52	31.9 (d)	30.74	1.18 (f)	20.69	12.34 (g)	8.35 (i)	65.13	2.52 (j)
2	Bituminous Coal, 190 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB, OFA, SCR	91%	2,352	8,880	0.772	0.060	141.09	0.262	615.12	0.041	97.46	Stack Test	69.20 (d)	19.49	49.7 (d)	47.87	1.84 (f)	23.32	13.91 (g)	9.41 (i)	92.52	2.85 (j)
3	Bituminous Coal, 253 MW, PC Wall-Fired, Dry Bottom, Venturi Scrubber, Wet FGD	LNB, OFA, SCR	90%	2,896	8,880	0.772	0.067	192.62	0.344	995.26	0.037	107.72	Stack Test	76.48 (d)	21.54	54.9 (d)	52.90	2.03 (f)	28.71	17.13 (g)	11.58 (i)	105.19	3.50 (j)
4	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	LNB, OFA, SCR	88%	8,000	8,880	0.772	0.075	601.92	0.253	2,026.10	0.025	197.75	Stack Test	181.926 (e)	77.12	104.81 (e)	100.93	3.88 (f)	35.32	3.32 (h)	32.00 (i)	217.24	9.68 (j)
5	Bituminous Coal, 818 MW, PC Cell Burner, Dry Bottom, Fabric Filter, Semi-Dry FGD	LNB, OFA, SCR	88%	8,047	8,880	0.772	0.066	533.29	0.265	2,130.76	0.012	94.04	Stack Test	86.515 (e)	36.67	49.84 (e)	48.00	1.84 (f)	35.52	3.34 (h)	32.19 (i)	122.04	9.73 (j)

(a) Maximum heat input rate are based worst-case daily emissions for calendar years 2002 through 2006.
(b) Higher heating values and sulfur content are based on the average values for calendar years 2002 through 2006.
(c) Baseline NOx, SO2 and filterable PM emissions are based worst-case daily emissions received on March 2, 2007 and revised April 26, 2007.
(d) For a dry bottom boiler fired with bituminous coal and equipped with a scrubber, total filterable PM10 is 71% of filterable PM and fine filterable PM10 is 51% of filterable PM based on AP-42, Table 1.1-6.
(e) For a dry bottom boiler fired with bituminous coal and equipped with a bagouse, total filterable PM10 is 92% of filterable PM and fine filterable PM10 is 53% of filterable PM based on AP-42, Table 1.1-6.
(f) Elemental carbon is 3.7% of fine PM based on the best estimate for electric utility coal combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.
(g) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers equipped with SCR, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1+S2)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), S2 is the SCR catalyst SO2 oxidation rate (0.5% for western bituminous coal), and F2 is the control factor (0.56 for an air preheater and 0.65 for a venturi scrubber).
(h) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," EPRI, Technical Update, March 2007. For coal-fired boilers equipped with SCR, H2SO4 emissions are determined from "(Q)(98.06/64.04)(F1+S2)(F2)" where Q is the uncontrolled SO2 emission rate (lb/hr), F1 is the fuel factor (0.00111 for western bituminous coal), S2 is the SCR catalyst SO2 oxidation rate (0.5% for western bituminous coal), and F2 is the control factor (0.56 for an air preheater, 0.40 for a wet spray tower, and 0.10 for a baghouse).
(i) For pulverized coal-fired boilers with an FGD system, total condensable organic PM10 emissions factor is 0.004 lb/MMBtu based on AP-42, Table 1.1-5.
(j) Ammonia slip is 2.00 ppmvd at 6% O2 for SCR.

6.2 CALPUFF Results and Visibility Improvement Analysis

The results of the BART control options modeling are presented in Tables 6-5 and 6-6 for PM_{10} and NO_x controls. Results are also plotted in Figure 6-1. Table 6-5 presents overall summaries, averaged over the seven closest Class I areas and the three modeled years, of the regional haze improvements and degradation due to installation of the BART controls on FCPP units. Table 6-6 show detailed regional haze impacts of the PM_{10} and NO_x BART control options for each modeled Class I area and meteorological year.

Table 6-5 indicates that the fabric filter controls for Units 1-3 would have very little visibility benefit (an average of 0.01 dv over the 7 closest Class I areas), but at a substantial cost. As expected, the addition of the fabric filter controls for PM emissions provides very little improvement, because direct PM emissions are not substantially contributing to regional haze.

Tables 6-5 and 6-6 indicate that the BART NO_x controls result in visibility benefits as well as some visibility degradation in some cases (shown in red in Table 6-6). The results show that the regional haze impacts may improve visibility by an average of 0.16 delta-dv (relative to the baseline case) with the installation of LNB on Units 1-2 and LNB/OFA on Units 3-4-5 (NOx Control Option 1).

Addition of SNCR (NOx Control Option 2) actually shows a regional haze degradation (0.21 delta-dv) at Mesa Verde National Park and a slight regional haze improvement (0.14 delta-dv) when averaged over the seven closest Class I areas. The visibility degradation in some areas is a result of excess ammonia emissions associated with the SNCR operations which increase the ambient ammonia concentration by about 0.2 ppb and result in additional sulfate and nitrate particulate formation. Therefore, NO_x BART control option 2 is not effective in improving visibility.

Addition of SCR (NOx Control Option 3) is projected to improve visibility by about 0.44 delta-dv from the baseline case, and only about 0.28 delta-dv from NO_x BART control option 1, but at a very substantial cost. The relatively small incremental improvement in visibility is due in part to the small role that nitrates play in the total regional haze contribution. In addition, the installation of SCR would create new emissions of primary sulfates (H_2SO_4) and excess ammonia, partially offsetting any available NO_x reduction benefit to visibility. This is especially true during the high visitation period of the warm weather months, when nitrates have minimal contribution to visibility impairment, but sulfates have an important role. Therefore, NO_x emission controls involving SCR are relatively ineffective in this case, especially taking into account the high cost of the controls.

Table 6-5 Regional Haze Impact of BART Controls

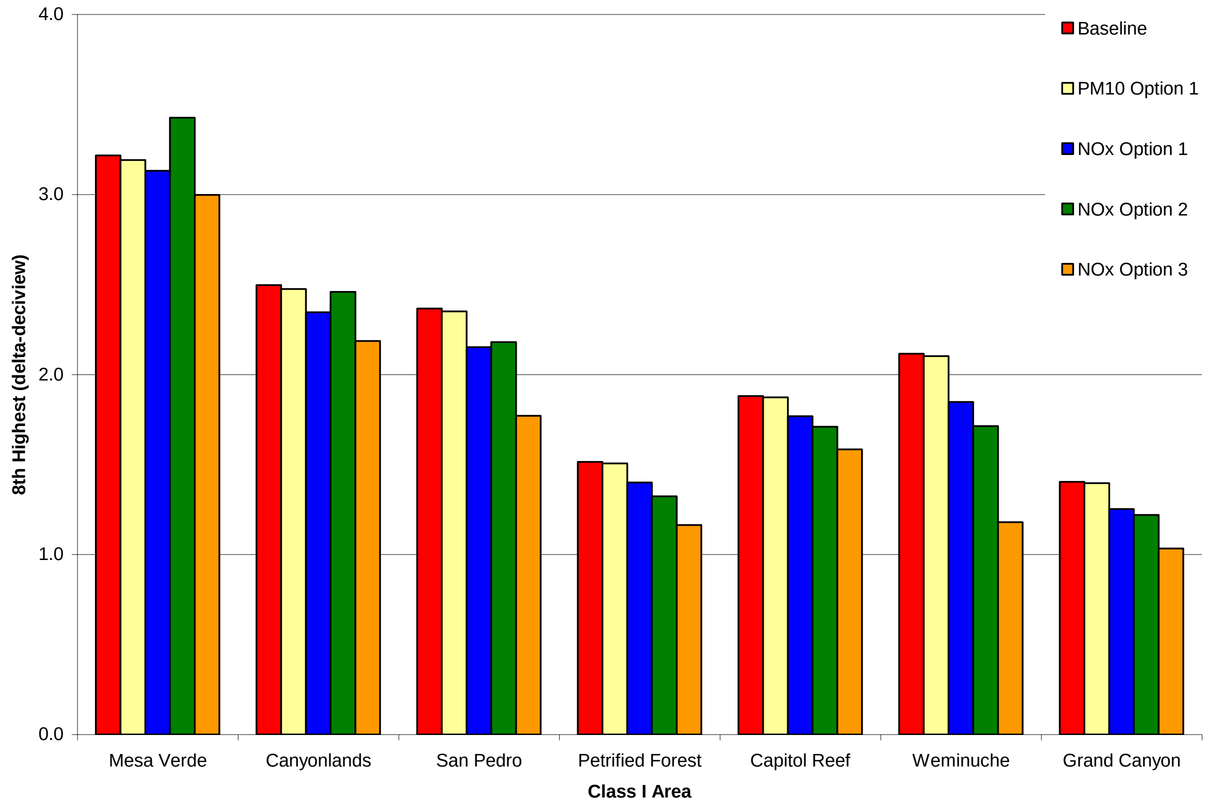
Class I Area	Option	BART Controls	2001	2002	2003	2001-2003 Ave	Benefit of Controls from Baseline, delta-dv
			8th Highest dv Δ B_{ext}				
Average of 7 Class I Areas (1)	Baseline	None	2.28	2.11	2.04	2.14	**0.00**
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	2.11	1.98	1.86	1.99	**0.16**
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	2.17	1.98	1.87	2.00	**0.14**
	NOx Option 3	LNB/OFA/SCR (1-5)	1.87	1.66	1.57	1.70	**0.44**
	PM10 Option 1	FF (1-3)	2.26	2.10	2.02	2.13	**0.01**

(1) Seven Class I areas are: Grand Canyon, Capitol Reef, Canyonlands, Mesa Verde, Petrified Forest, Weminuche, San Pedro.

Table 6-6 Regional Haze Results of BART Controls on Each Class I Areas

Class I Area	Option	BART Controls	Met Year 2001 8th Highest Δ dv	Met Year 2002 8th Highest Δ dv	Met Year 2003 8th Highest Δ dv	Ave 01-03 8th Highest Δ dv	Change from Baseline, dv
Mesa Verde	Baseline	None	2.77	3.64	3.25	3.22	0.00
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	2.74	3.61	3.05	3.13	0.09
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	3.26	3.66	3.35	3.43	-0.21
	NOx Option 3	LNB/OFA/SCR (1-5)	2.89	3.18	2.92	3.00	0.22
	PM10 Option 1	FF (1-3)	2.75	3.60	3.22	3.19	0.03
Canyonlands	Baseline	None	2.93	2.23	2.34	2.50	0.00
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	2.68	2.13	2.23	2.35	0.15
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	2.85	2.34	2.19	2.46	0.04
	NOx Option 3	LNB/OFA/SCR (1-5)	2.68	1.94	1.94	2.19	0.31
	PM10 Option 1	FF (1-3)	2.89	2.22	2.31	2.47	0.02
San Pedro	Baseline	None	2.27	2.50	2.33	2.37	0.00
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	2.13	2.26	2.06	2.15	0.21
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	2.19	2.23	2.11	2.18	0.19
	NOx Option 3	LNB/OFA/SCR (1-5)	1.74	1.83	1.74	1.77	0.60
	PM10 Option 1	FF (1-3)	2.25	2.48	2.32	2.35	0.02
Petrified Forest	Baseline	None	1.81	1.50	1.23	1.51	0.00
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	1.62	1.40	1.17	1.40	0.11
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	1.48	1.39	1.10	1.32	0.19
	NOx Option 3	LNB/OFA/SCR (1-5)	1.24	1.19	1.06	1.16	0.35
	PM10 Option 1	FF (1-3)	1.81	1.49	1.22	1.51	0.01
Capitol Reef	Baseline	None	2.47	1.56	1.61	1.88	0.00
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	2.29	1.48	1.53	1.77	0.11
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	2.16	1.47	1.50	1.71	0.17
	NOx Option 3	LNB/OFA/SCR (1-5)	1.95	1.42	1.38	1.58	0.30
	PM10 Option 1	FF (1-3)	2.46	1.55	1.61	1.87	0.01
Weminuche	Baseline	None	1.87	2.20	2.27	2.12	0.00
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	1.69	1.94	1.91	1.85	0.27
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	1.62	1.74	1.78	1.71	0.40
	NOx Option 3	LNB/OFA/SCR (1-5)	1.23	1.24	1.06	1.18	0.94
	PM10 Option 1	FF (1-3)	1.86	2.20	2.25	2.10	0.01
Grand Canyon	Baseline	None	1.84	1.15	1.22	1.40	0.00
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	1.63	1.04	1.09	1.25	0.15
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	1.60	1.03	1.03	1.22	0.18
	NOx Option 3	LNB/OFA/SCR (1-5)	1.34	0.84	0.92	1.03	0.37
	PM10 Option 1	FF (1-3)	1.83	1.15	1.21	1.40	0.01
Average of 7 Class I Areas	Baseline	None	2.28	2.11	2.04	2.14	0.00
	NOx Option 1	LNB (1-2) LNB/OFA (3-5)	2.11	1.98	1.86	1.99	0.16
	NOx Option 2	LNB/OFA/HERT (1-3) LNB/OFA/SNCR (4-5)	2.17	1.98	1.87	2.00	0.14
	NOx Option 3	LNB/OFA/SCR (1-5)	1.87	1.66	1.57	1.70	0.44
	PM10 Option 1	FF (1-3)	2.26	2.10	2.02	2.13	0.01

Figure 6-1 8th Highest Regional Haze Impacts Averaged Over 3 Years For Baseline and BART Control Emissions



6.3 Effectiveness of BART Control Options

Tables 6-7 and 6-8 summarize the annualized control cost that is the product of the $/ton removed and the number of tons of PM_{10} and NO_x, respectively, removed by each control strategy. The tables also include an incremental computation of each control option's visibility improvement/degradation effectiveness and cost. The visibility results in these tables are based on the average of the three years and the seven modeled Class I areas. Figures 6-2 and 6-3 show graphs of visibility improvements/degradation as a function of the cost for each control option for PM_{10} and NO_x, respectively. BART options associated with incremental improvements in visibility relative to a previous beneficial control option are connected with a blue line. The table and the figure both show a very large increase in the cost per deciview improvement slope for the only PM_{10} control option. A large cost per unit visibility improvement is also evident beyond BART NO_x Control Option 1 (combustion controls), indicating that post-combustion NO_x controls are not cost-effective for improving visibility, and that the visibility improvement for SCR controls would be below half of the detection limit and would therefore be imperceptible.

Table 6-7 Visibility Improvement and Annual Costs for PM_{10} Control Options

Option	BART Controls	Annualized Cost	8th Highest Ave over 3 Years in 7 Class I Areas	Incremental Deciview Reduction (Relative to the Previous Case)	Incremental Cost Effectiveness (Relative to the Previous Case)
		($/Year)	(delta-dv)	(delta-dv))	($/delta-dv)
Baseline	None	$0	2.14	0.00	$0
PM_{10} Option 1	FF (1-3)	$44,990,000	2.13	0.014	$3,118,118,812

Table 6-8 Visibility Improvement and Annual Costs for NO_x Control Options

Option	BART Controls	Annualized Cost	8th Highest Ave over 3 Years in 7 Class I Areas	Incremental Deciview Reduction (Relative to the Previous Case)	Incremental Cost Effectiveness (Relative to the Previous Case)
		($/Year)	(delta-dv)	(delta-dv))	($/delta-dv)
Baseline	None	$0	2.14	0.000	$0
NO_x Option 1	LNB Units 1-5 OFA Units 3-4-5	$8,709,000	1.99	0.157	$55,640,097
NO_x Option 2	LNB/OFA/SNCR	$23,765,000	2.00	-0.019	Not effective, visibility degrades
NO_x Option 3	LNB/OFA/SCR	$161,892,000	1.70	0.303	$456,366,740

Figure 6-2 Annualized Control Cost for PM_{10} BART Control Option vs. Visibility Impairment

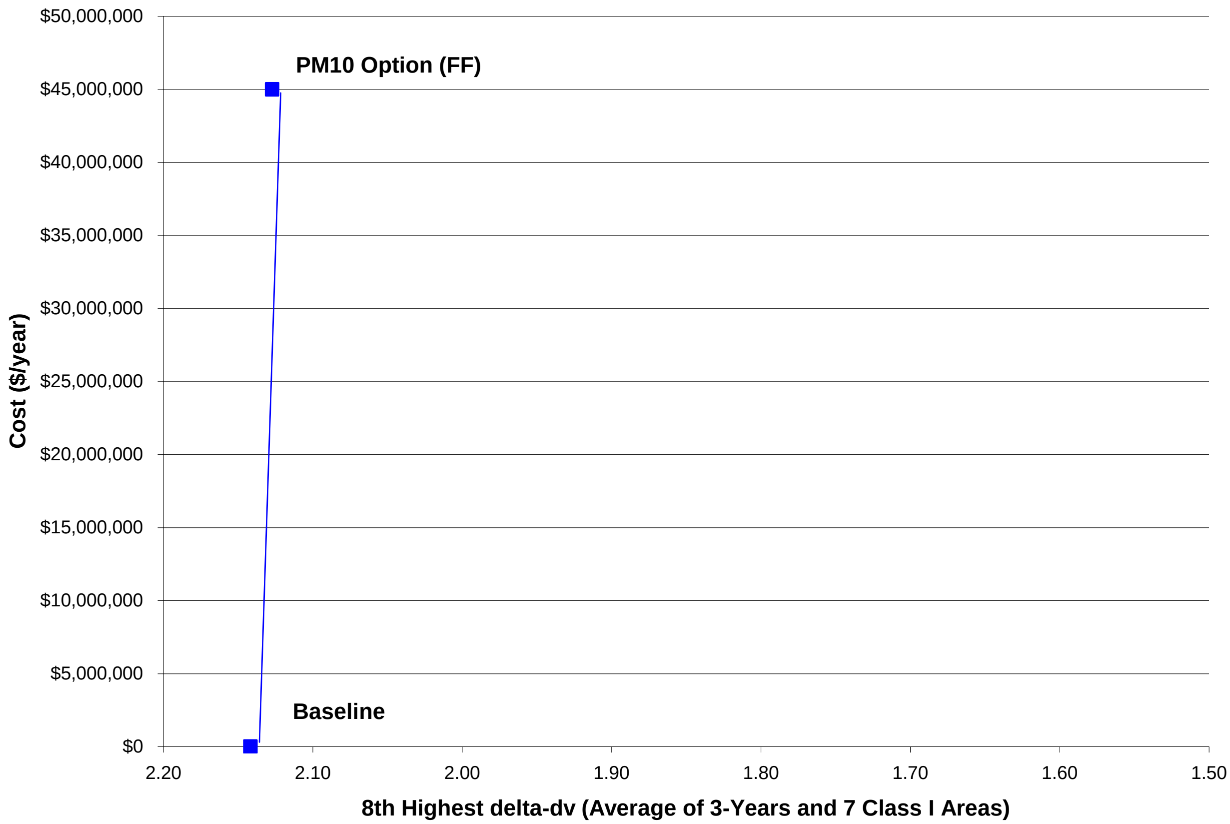
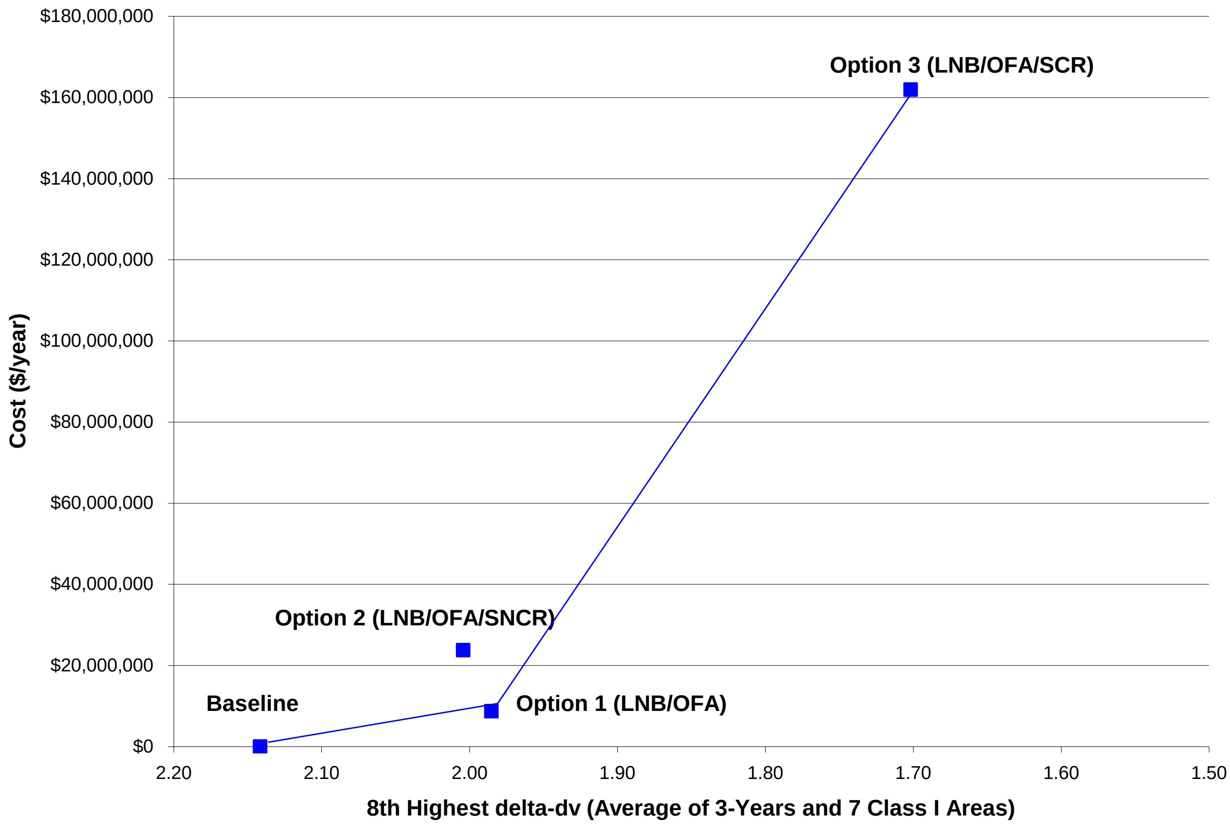


Figure 6-3 Annualized Control Cost for NO_x BART Control Options vs. Visibility Impairment



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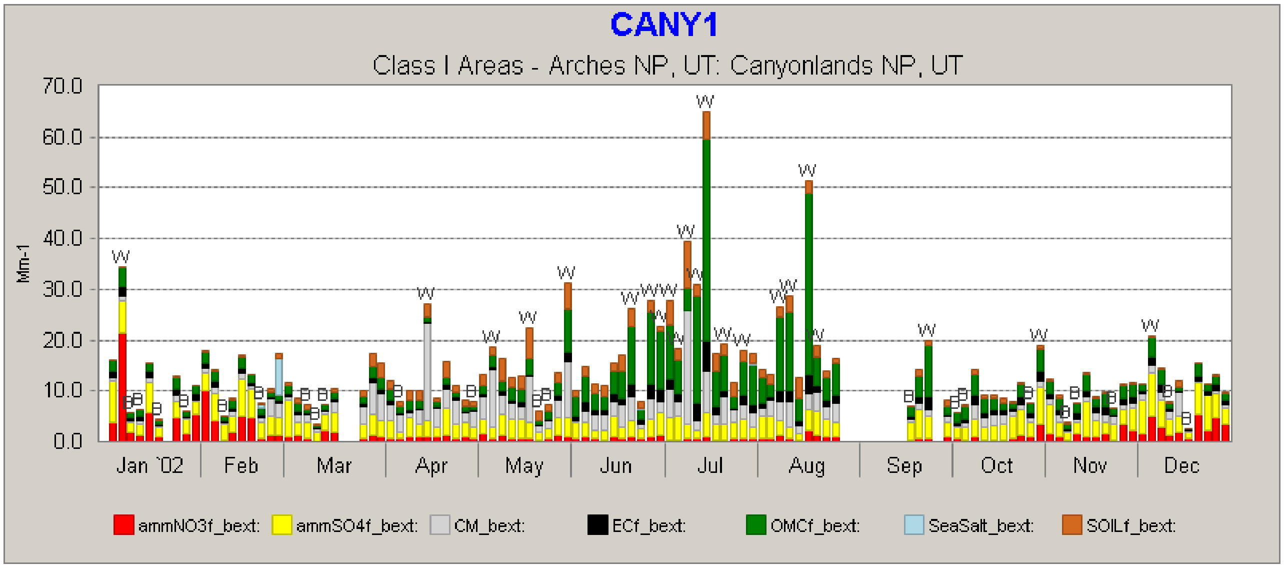
Appendix A

IMPROVE Monitoring Data

Figure A-1 Plot of Measured Visibility-Degrading Pollutants in Arches NP and Canyonlands NP, Year 2002



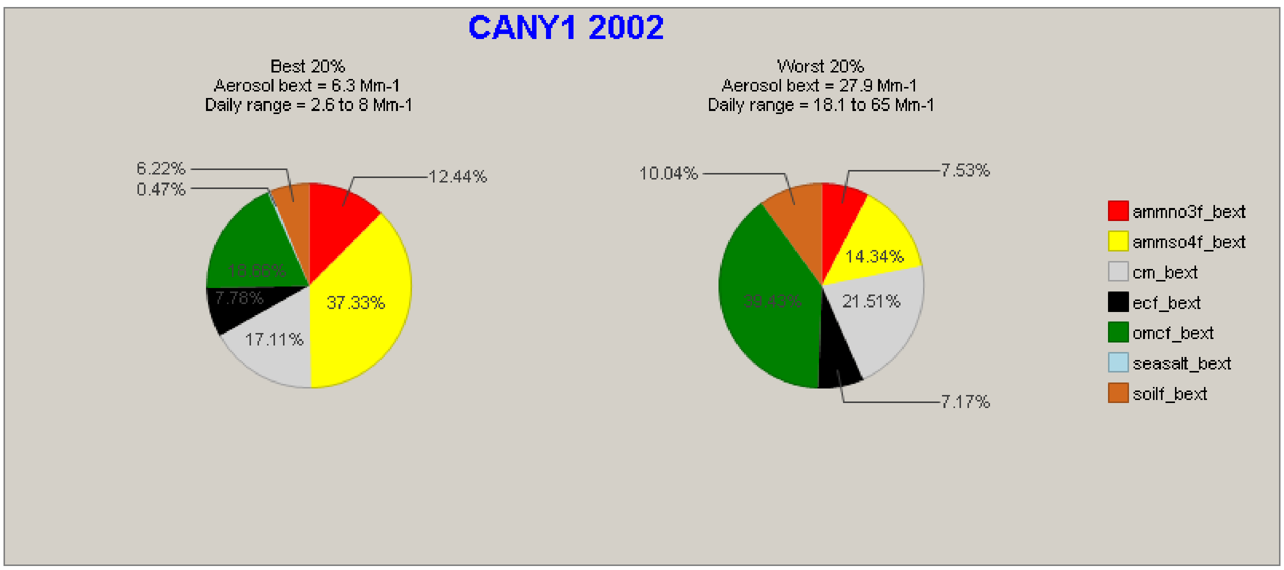
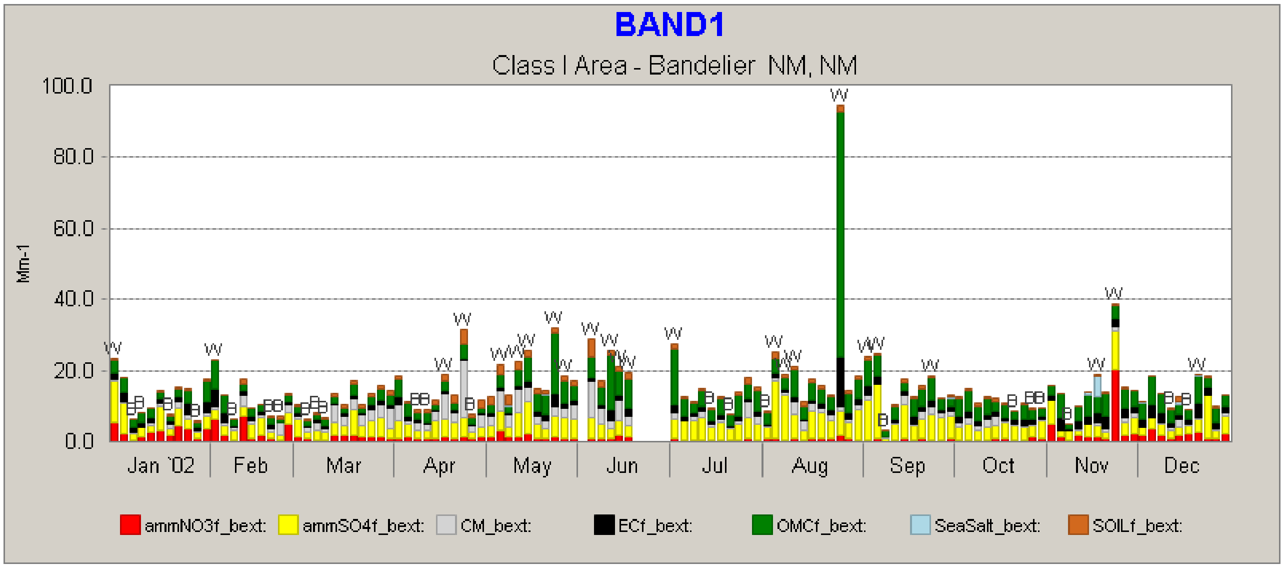


Figure A-2 Plot of Measured Visibility-Degrading Pollutants in Bandelier W, Year 2002



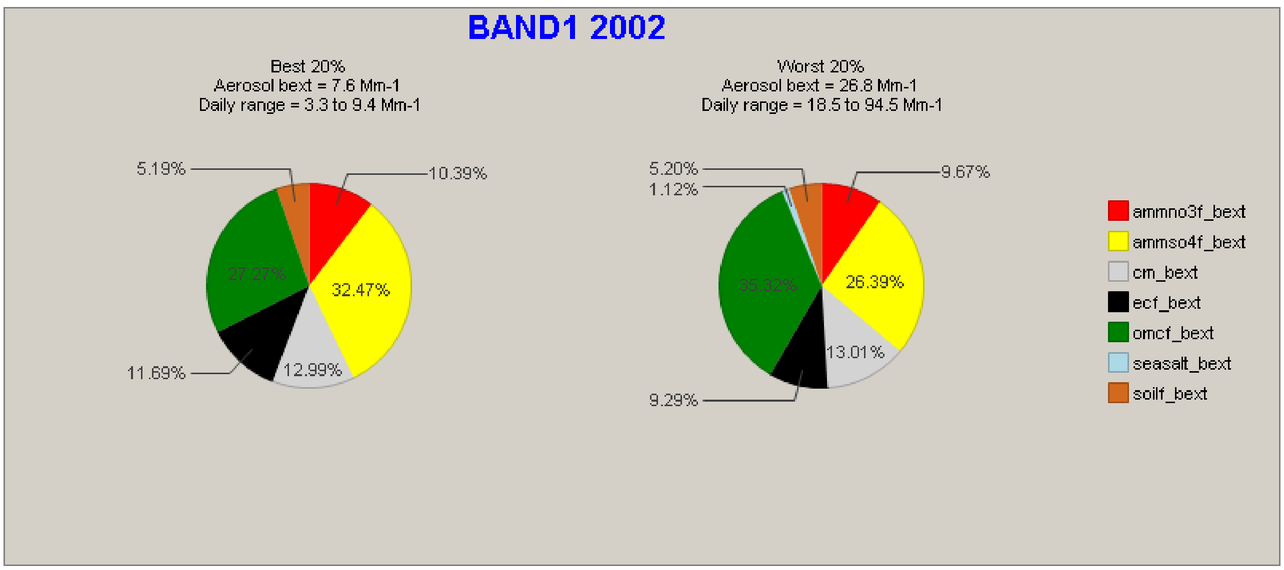
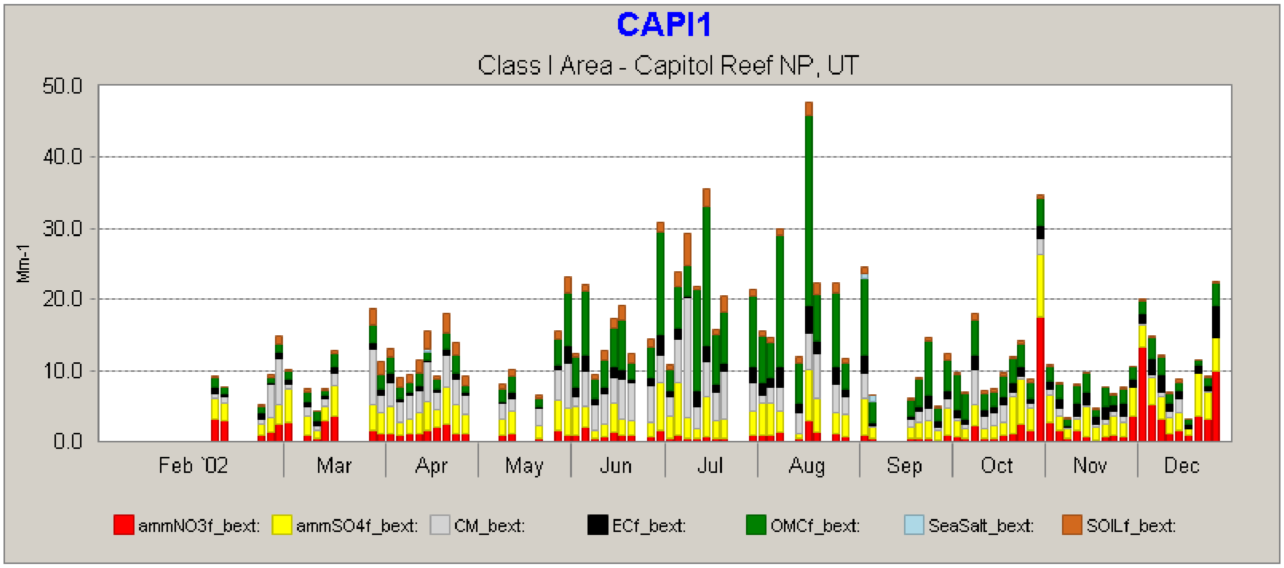
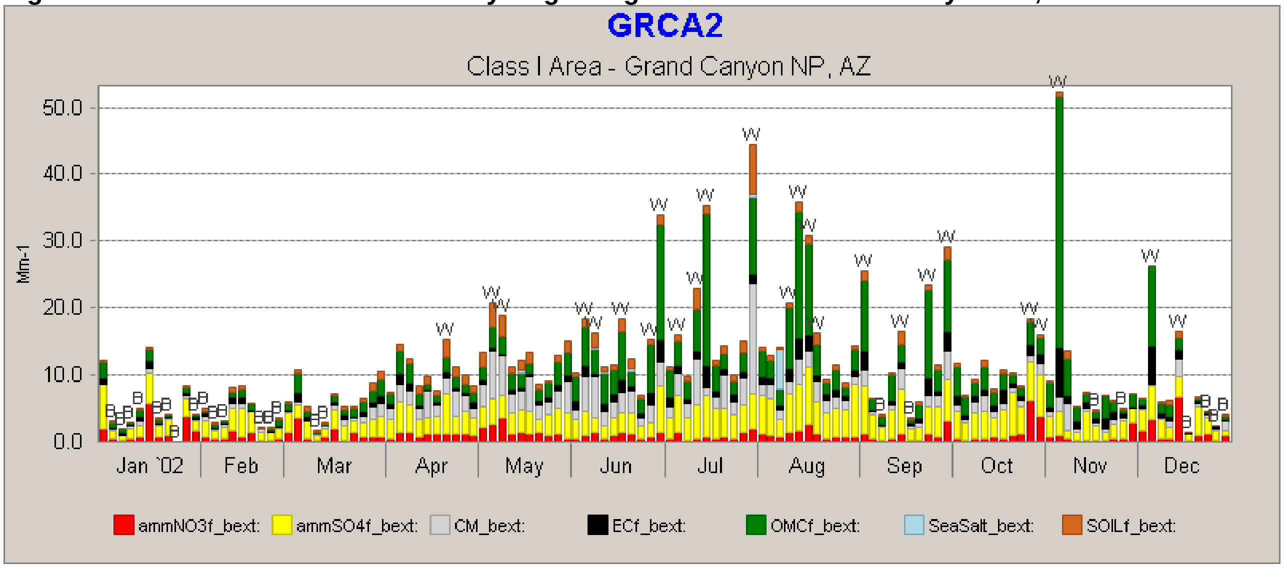


Figure A-3 Plot of Measured Visibility-Degrading Pollutants in Capitol Reef NP, Year 2002



Pie chart for Capitol Reef NP is not available.

Figure A-4 Plot of Measured Visibility-Degrading Pollutants in Grand Canyon NP, Year 2002



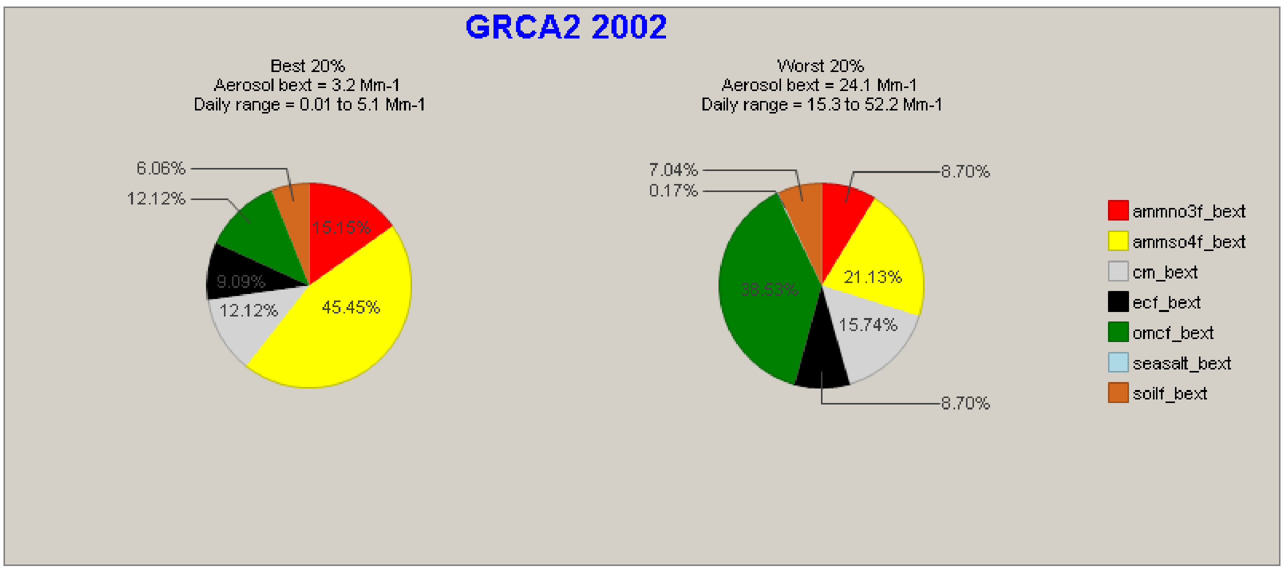
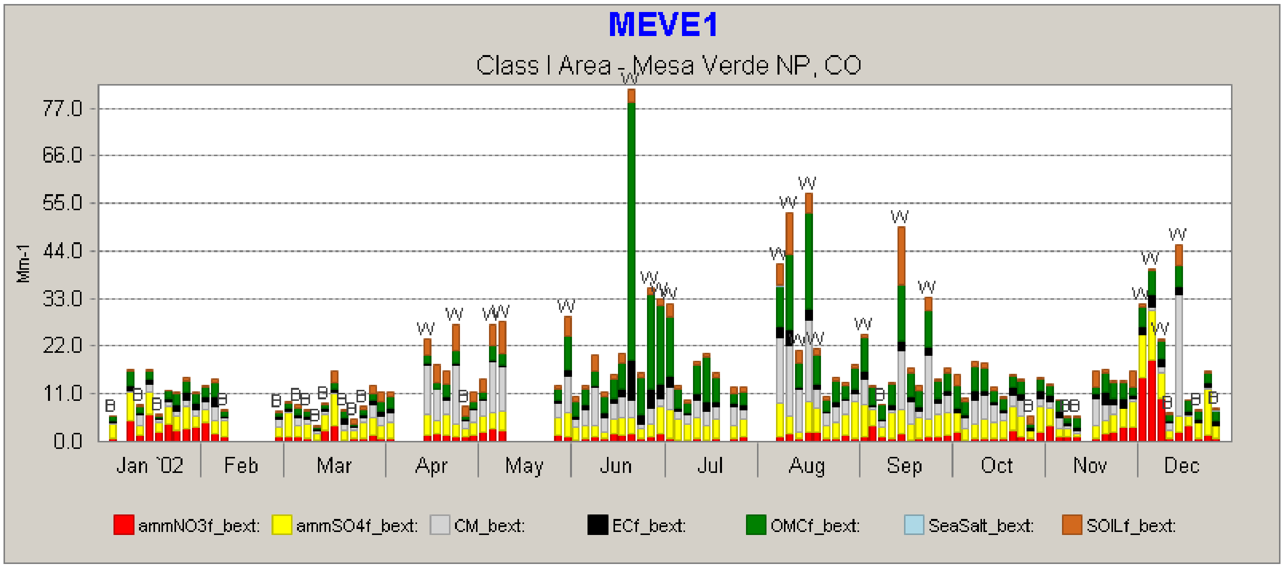


Figure A-5 Plot of Measured Visibility-Degrading Pollutants in Mesa Verde NP, Year 2002



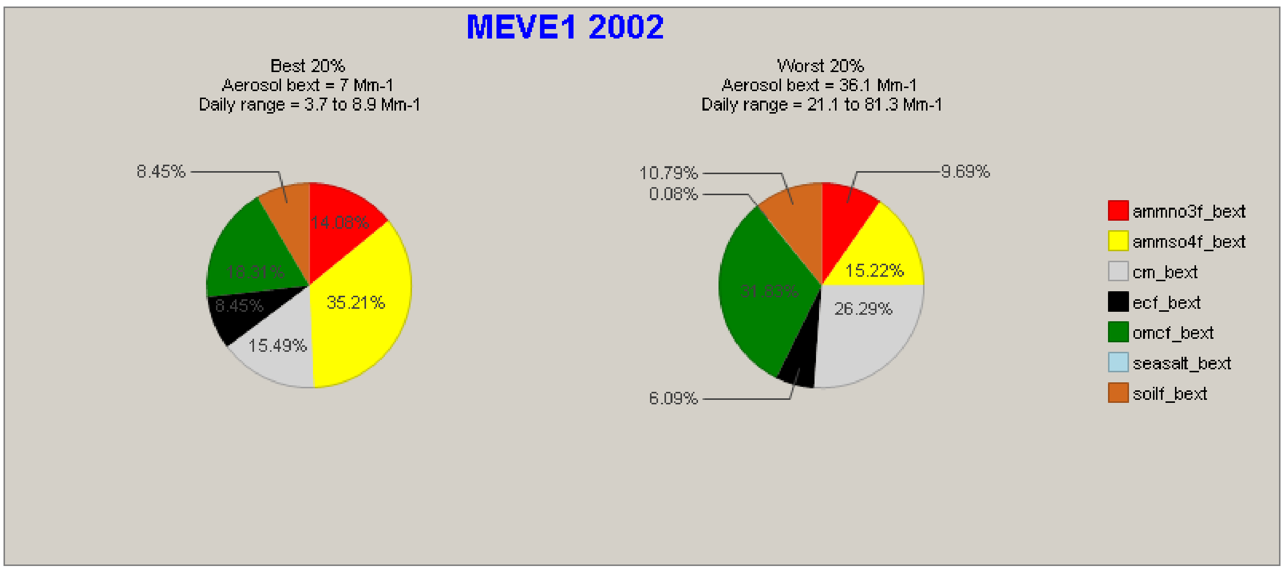
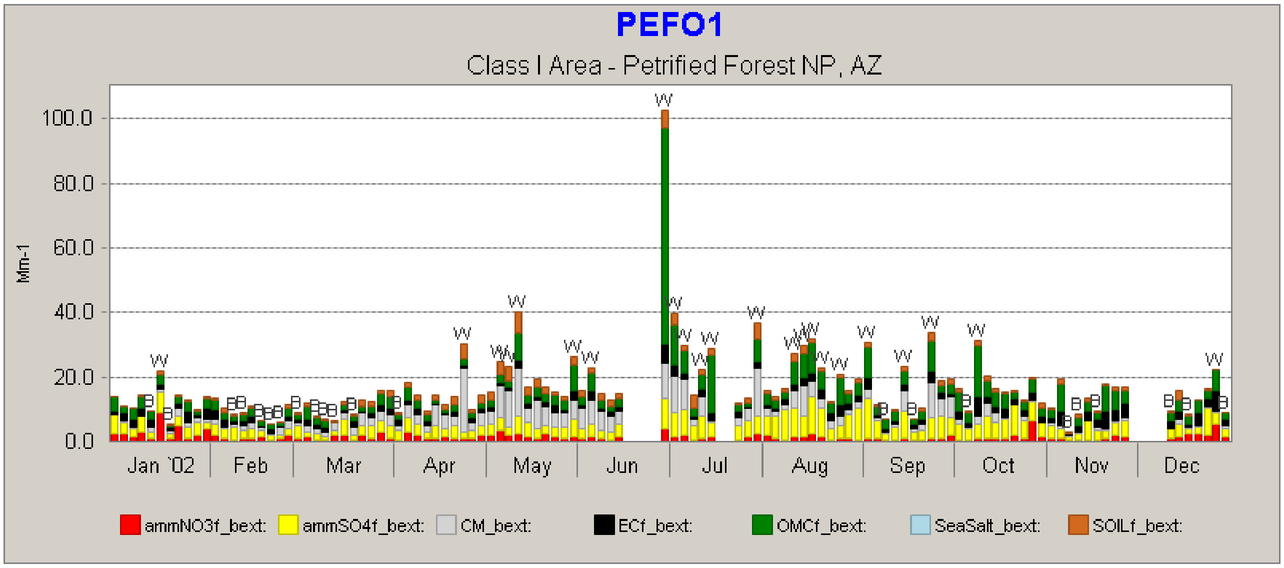


Figure A-6 Plot of Measured Visibility-Degrading Pollutants in Petrified Forest NP, Year 2002



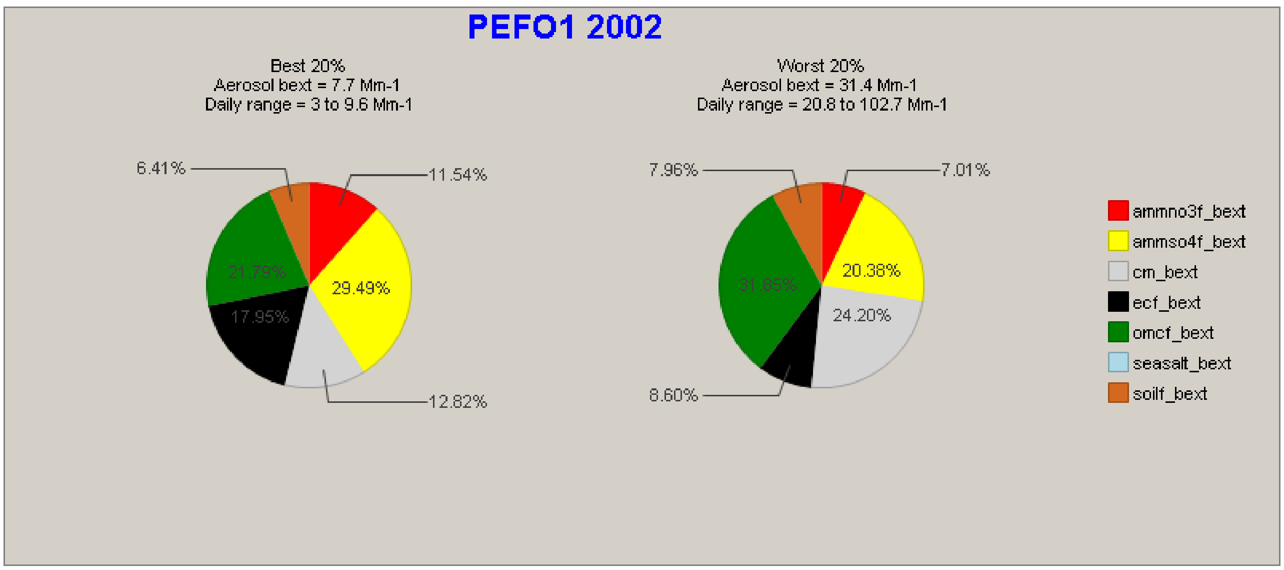
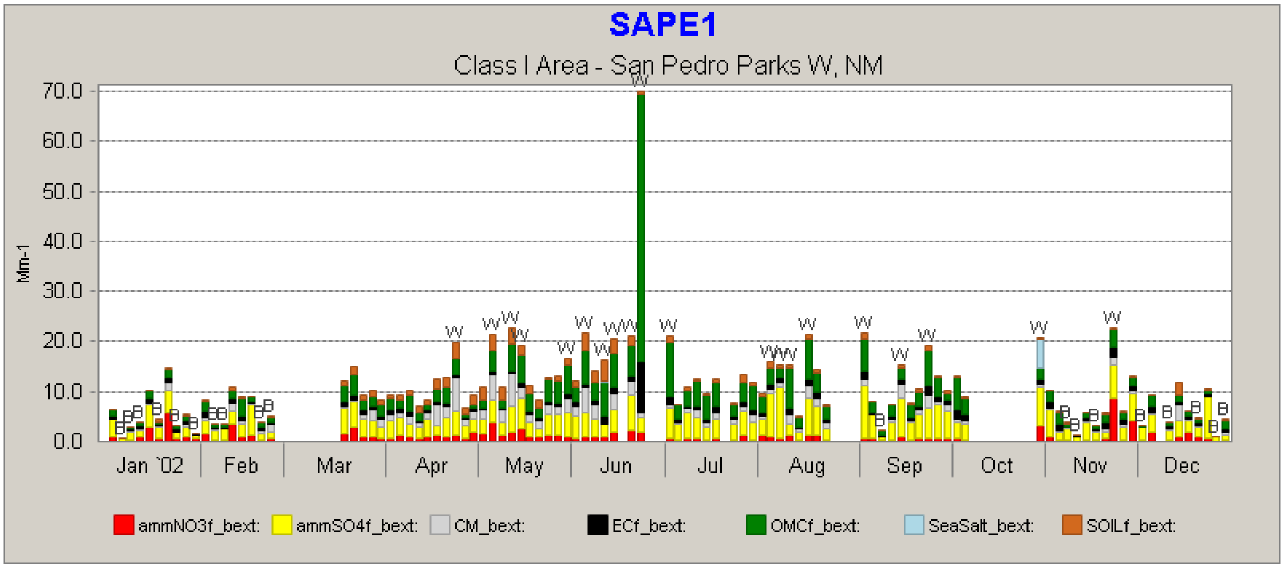


Figure A-7 Plot of Measured Visibility-Degrading Pollutants in San Pedro W, Year 2002



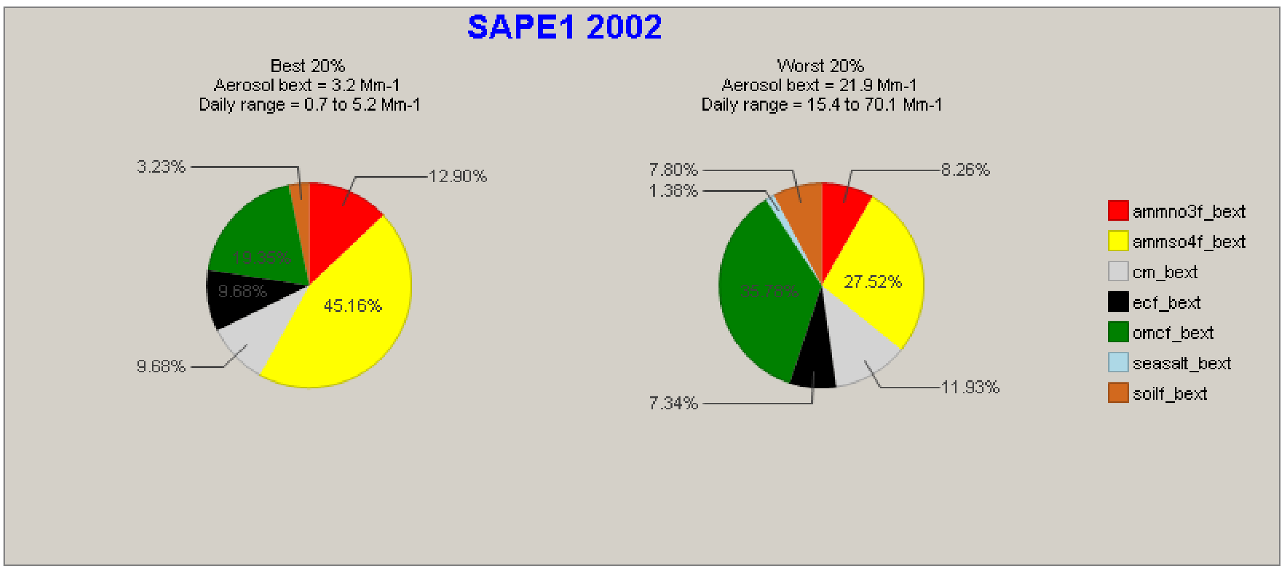
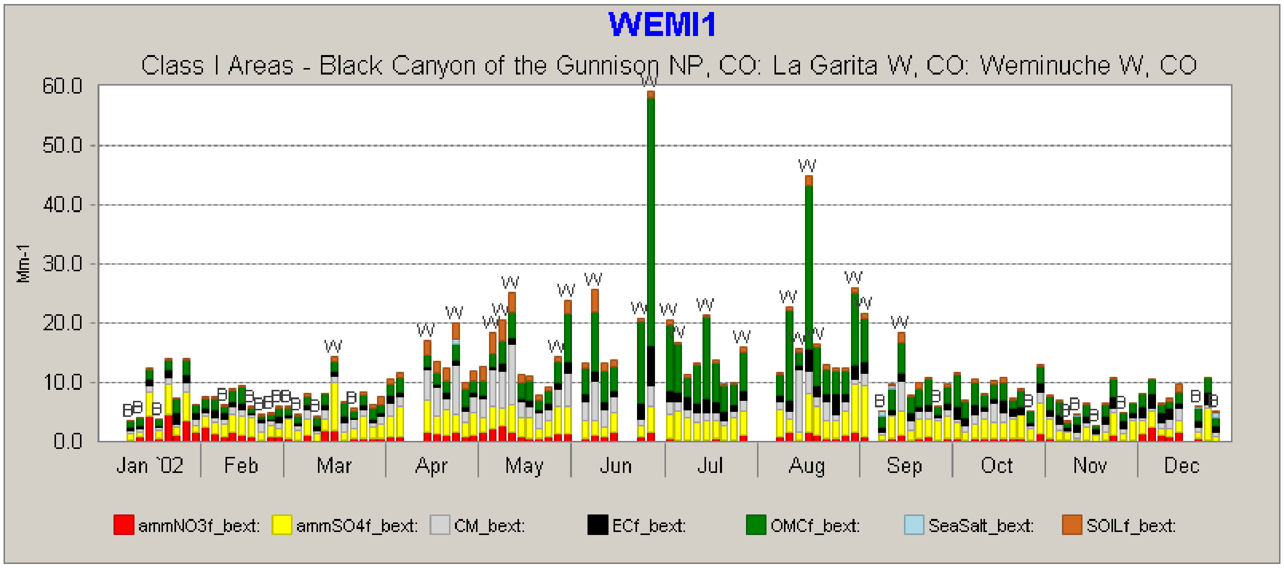


Figure A-8 Plot of Measured Visibility-Degrading Pollutants in Weminuche W, La Garita W, Black Canyon of the Gunnison W, Year 2002



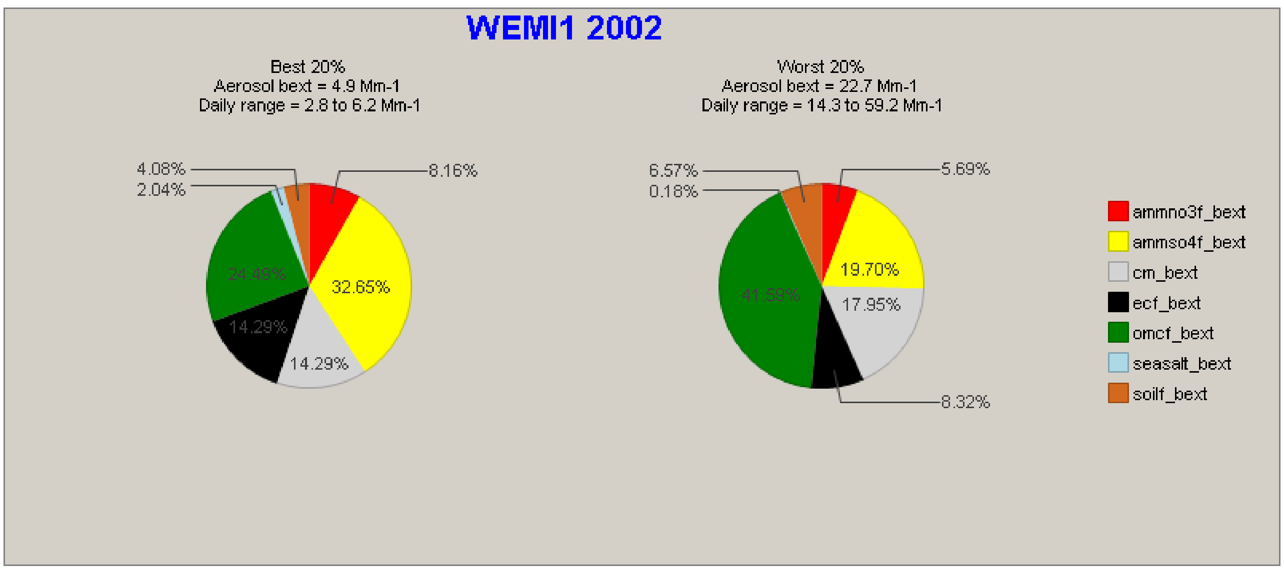
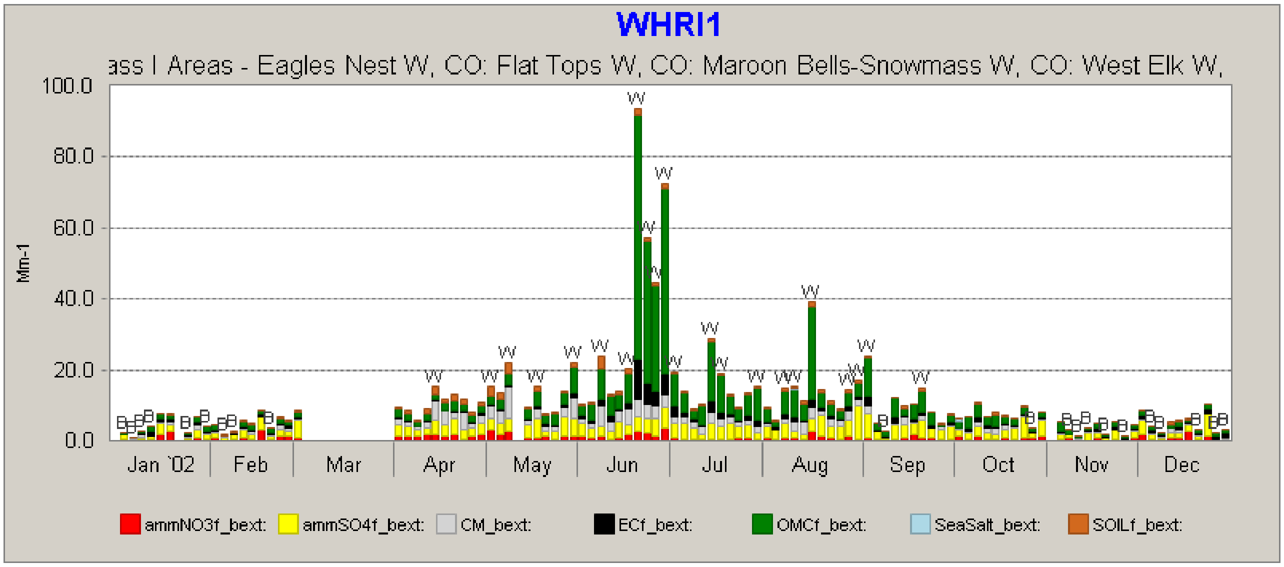


Figure A-9 Plot of Measured Visibility-Degrading Pollutants in Maroon Bells W and West Elk W, Year 2002



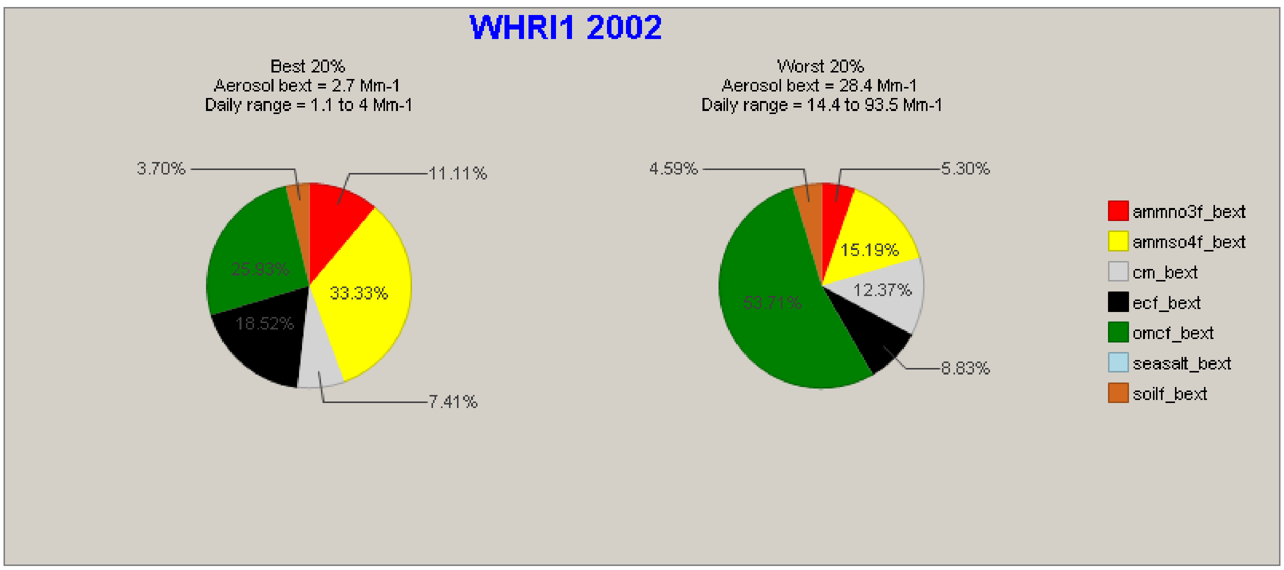
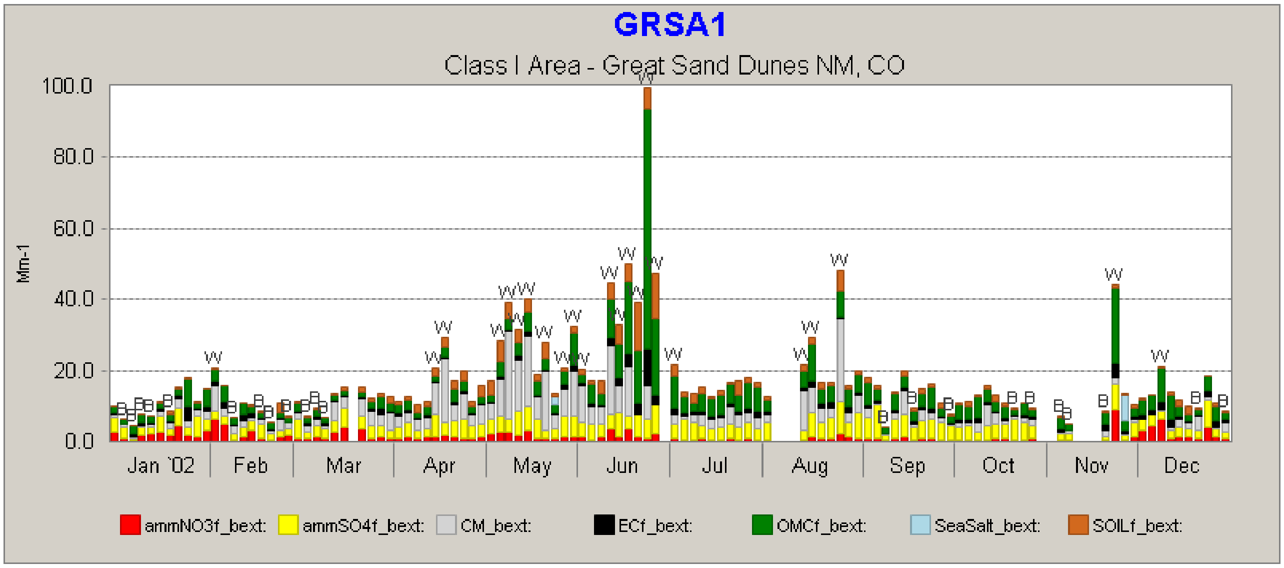


Figure A-10 Plot of Measured Visibility-Degrading Pollutants in Great Sand Dunes W, Year 2002



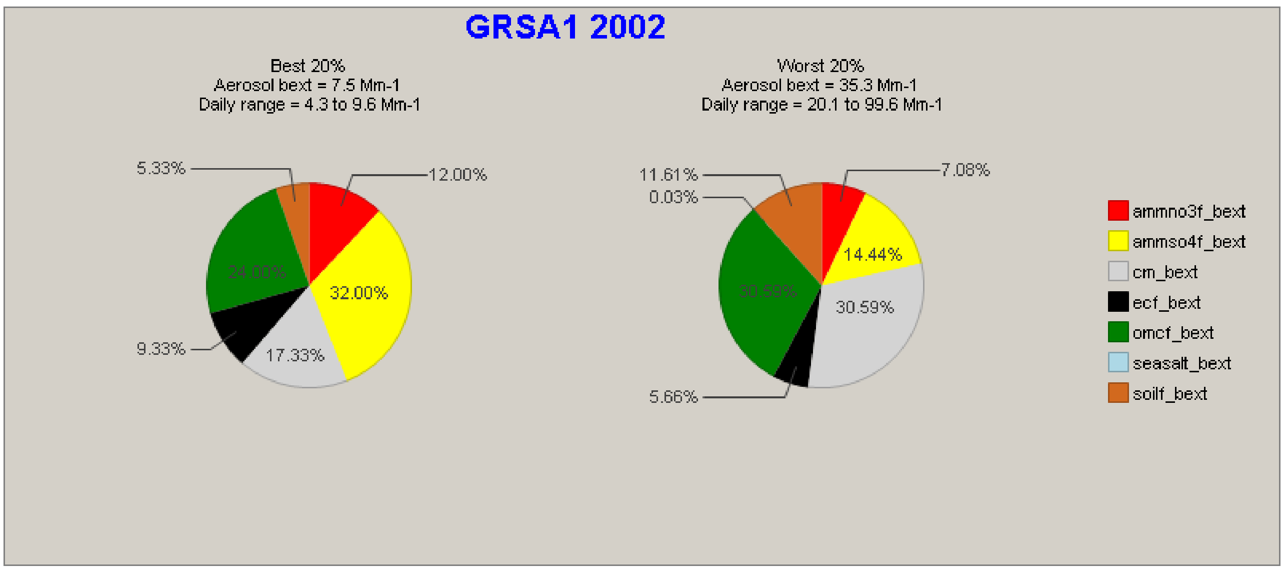
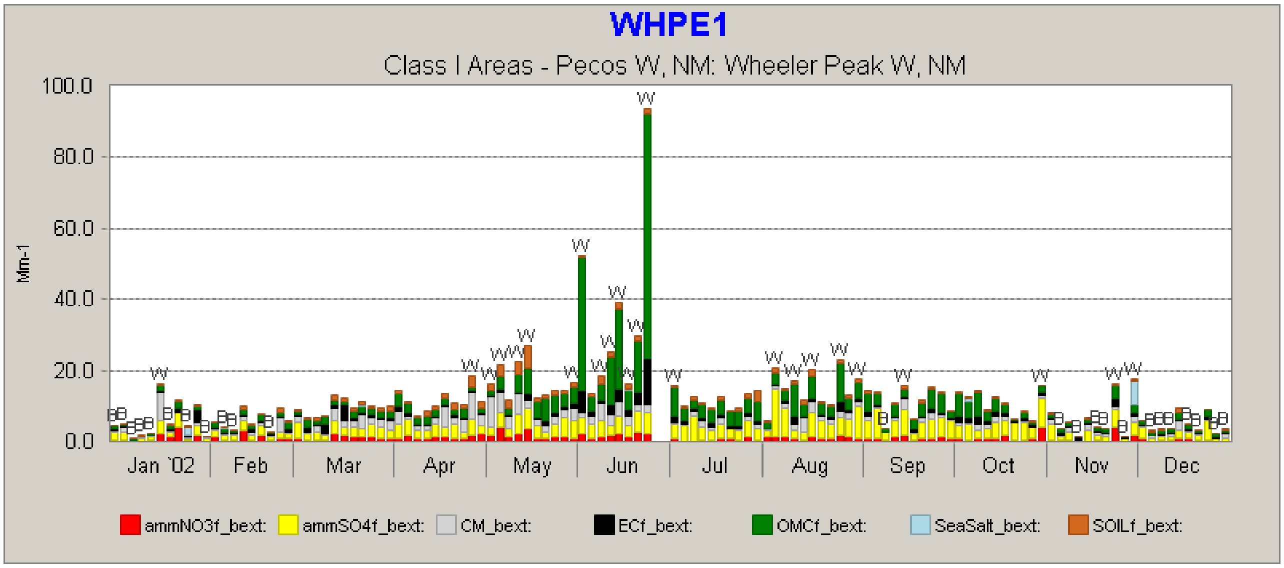
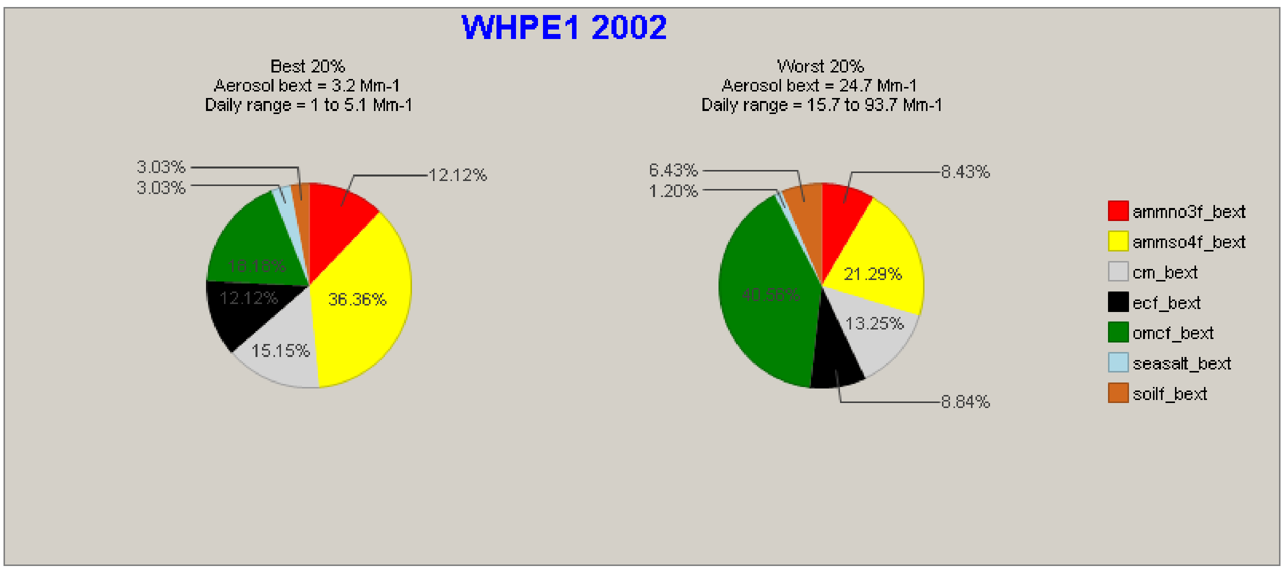


Figure A-11 Plot of Measured Visibility-Degrading Pollutants in Pecos W and Wheeler Peak W, Year 2002





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